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PROJECT REPORT:

STIMULATING THE U.S. SHIPBUILDING  
INDUSTRY TO IMPROVE PRODUCTIVITY

Transportation  
Research Institute

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>1979</b>		2. REPORT TYPE <b>N/A</b>		3. DATES COVERED <b>-</b>	
4. TITLE AND SUBTITLE <b>Project Report: Stimulating the U.S. Shipbuilding Industry to Improve Productivity</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Bldg Bethesda, MD 20817-5700</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release, distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>SAR</b>	18. NUMBER OF PAGES <b>102</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

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## EXECUTIVE SUMMARY

During the period from October 29 through November 16, 1979 a U.S. team of six individuals with broad shipbuilding experience visited six Japanese shipyards. The intent of this visit was to identify and examine low investment, high return Japanese shipbuilding technology. The objective of this project is to stimulate U.S. shipbuilders to adapt and adopt these advanced techniques in their yards to improve productivity.

This report reflects the consensus findings and conclusions of the U.S. team and recommends several specific projects for the **National Shipbuilding Research Program (NSRP)**<sup>1</sup>.

Based on observations in the six Japanese yards visited, the following items are cited as the primary reasons for their high productivity:

- (1) The utilization and application of the logic and principals of zone planning and construction.
- (2) The development and use of a very effective material classification scheme for definition, procurement, and control of material.
- (3) The extensive use and continual development of high quality shipbuilding standards and modules.
- (4) The rationalized development and use of effective cost/manhour reducing computer aids.

While these techniques and methods are of unquestioned value in achieving productivity improvements, it is also important to note the human aspects of their application. Japanese shipbuilding personnel are highly educated, trained, motivated and experienced managers and workers, and, therefore exhibit a very high level of individual productivity.

The following are a list of recommended projects (described in detail in section (6.1):

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<sup>1</sup> The NSRP is a cooperative effort between the Maritime Administration's Office of Advanced Ship Development (the sponsor of this project) and the U.S. shipbuilding industry.

- (1) Zone Planning - An expanded text of Outfit Planning to include hull and painting aspects of zone construction.
- (2) Zone Planning Example - a pamphlet containing examples of diagrammatics, material ordering zones, block breakdown, pallet lists etc. for a IHI ship which would most characterize U.S. ship construction.
- (3) Zone Planning Educational Aids - Educational aids in written and graphic form to assist lower and middle management in implementation.
- (4) Handbook for Production Process Planning and Engineering - manual on the function and methods of production process planning and engineering as practiced by the most successful Japanese shipbuilders.
- (5) Electric Cable Palletizing - A pamphlet describing the methods of precutting cable for palletizing and installation.
- (6) Shipbuilding Standards: Long Term Objectives - The long term development of a comprehensive set of standards for functional and detail design, and production processes.
- (7) Shipbuilding Standards: Functional Design Standards for Machinery Spaces - Development of functional design standards for machinery spaces and related systems.
- (8) Construction Services - A manual illustrating and describing methods by which construction services could be installed to conveniently supply needed services in a preplanned manner.
- (9) Jigs, Fixtures and Special Tools - a manual illustrating and describing the use of these devices in both foreign and domestic shipyards.

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## 1.0 INTRODUCTION

In January 1979 a study entitled, Technology Survey of Major U.S. Shipyards<sup>[1]</sup> was completed and documented for the Maritime Administration by Marine Equipment Leasing, Inc. In the course of this survey the level of technology used by a cross section of U.S. shipyards was compared to the level of technology used by foreign shipyards.

One of the ground rules employed in this study was to ensure that at least one Japanese shipyard should be in each set of yards compared to each U.S. shipyard because of Japan's preeminence in world shipbuilding.

In conducting this study a major objective was to encourage individual U.S. shipyards to examine in depth the areas where the difference between U.S. technology and foreign technology is the greatest.

A significant conclusion of this study is that the first nine critical areas (Appendix A) in which U.S. Shipyards are using low technology are primarily management and systems (or methods) oriented, and, these nine areas would require minor capital investment to implement.

There are some indications that Japanese management techniques are not just applicable in the Japanese cultural environment but are applicable in the U.S. environment. Some data which support this conclusion are:

- The fact that SONY has established manufacturing facilities in the U.S. The one which is managed by Japanese personnel has greater productivity.
- Productivity (especially as it related to quality of product) has improved significantly at the Motorola Co. (now Quasar) since it has been purchased by Matsushita and Japanese management techniques introduced.

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<sup>1</sup>Numbers in brackets designate references at end of this report.

- Fujitsu Fanuc is about to open a factory in suburban Chicago to produce Numerical Controllers. The factory will be Japanese managed because Fujitsu feels this will insure high productivity.

In summary, the Japanese appear to have achieved high levels of productivity in shipbuilding as a result of the management and systems related approaches they are using.

## 2.0 PROJECT OBJECTIVES

There are examples of successful transfer of Japanese technology to U.S. shipbuilding in the areas of welding, automated pipe fabrication and other areas also requiring large capital investment. While this type of technology transfer is unquestionably valuable it was not the focus of this project.

Rather the objective of this project was to identify and examine low investment, high return Japanese technology (methods, procedures, management and organizational techniques) for the purpose of stimulating U.S. shipbuilders to adapt and adopt these techniques in their yards to improve productivity. This examination was made by a team of individuals having broad shipbuilding experience to:

1. Identify the specific techniques or methods
2. Prioritize the value of these techniques
3. Outline a plan for making these techniques available to U.S. shipbuilders in the most efficacious manner.

## 3.0 PROJECT TEAM

The U.S. team formulated for this project consisted of the following six individuals:

Louis D. Chirillo	Todd Pacific Shipyards Corp.
Peter E. Jaquith	Bath Iron Works Corp.
Charles E. Jonson	Science Applications, Inc.
John J. McQuaid	National Steel & Shipbuilding Co. (Retired)
Ellsworth L. Peterson	Peterson Builders, Inc.
James R. Vander Schaaf	IITRI (Project Director)

Summary biographies of these individuals are included in Appendix B.



#### 4.0 JAPANESE YARDS VISITED

The Japanese shipyards were selected based upon IITRI contacts with the leading shipbuilding companies in Japan and their expression of interest in participating in this project. The following organizations were visited during the period from October 29 through November 16, 1979:

1. Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI)
  - Kure Shipyard
  - Aioi Shipyard
  - Tokyo Shipyard
2. Mitsui Engineering & Shipbuilding Co., Ltd.
  - Tokyo Head Office
  - Chiba Shipyard
  - Tamano Shipyard
3. Nippon Kokan Kabushiki Kaisha (NKK)
  - Shimizu Shipyard

With the exception of the Mitsui Chiba Shipyard, all of these were old yards that had been modernized. In all cases, these shipyards were building orders of (1-4) vessels of non-standard design so a good comparison could be made with U.S. practice.

In 1978, the Japanese Government requested that all shipbuilders reduce their facilities by 35 percent in order to overcome the crisis caused by the oversupply of oil tankers and a lack of new orders. As a result all of the companies above have reduced their employment and have closed some of their new larger shipyards. IHI has closed its new Chita shipyard and NKK has closed its most modern yard at Tsu.

#### 5.0 KEY OBSERVATIONS

Notwithstanding the reduction in Japanese shipbuilding capacity, shipbuilding production was high by U.S. standards. As an example, the Mitsui Tomano shipyard produced 9 vessels (190,960 gross tons) in 1978 with a total shipyard workforce of 3370 plus 2500 individuals from subcontractor organizations. In all yards, direct labor

manhours and construction schedules were approximately one half when compared to U.S. practice. Observations relating to this high productivity and key factors influencing it are detailed in the following sections of this report.

### 5.1 Scheduling and Control

- A typical Japanese milestone schedule for the construction of a new design non-standard cargo, bulk, container or RO/RO Ship is as follows:

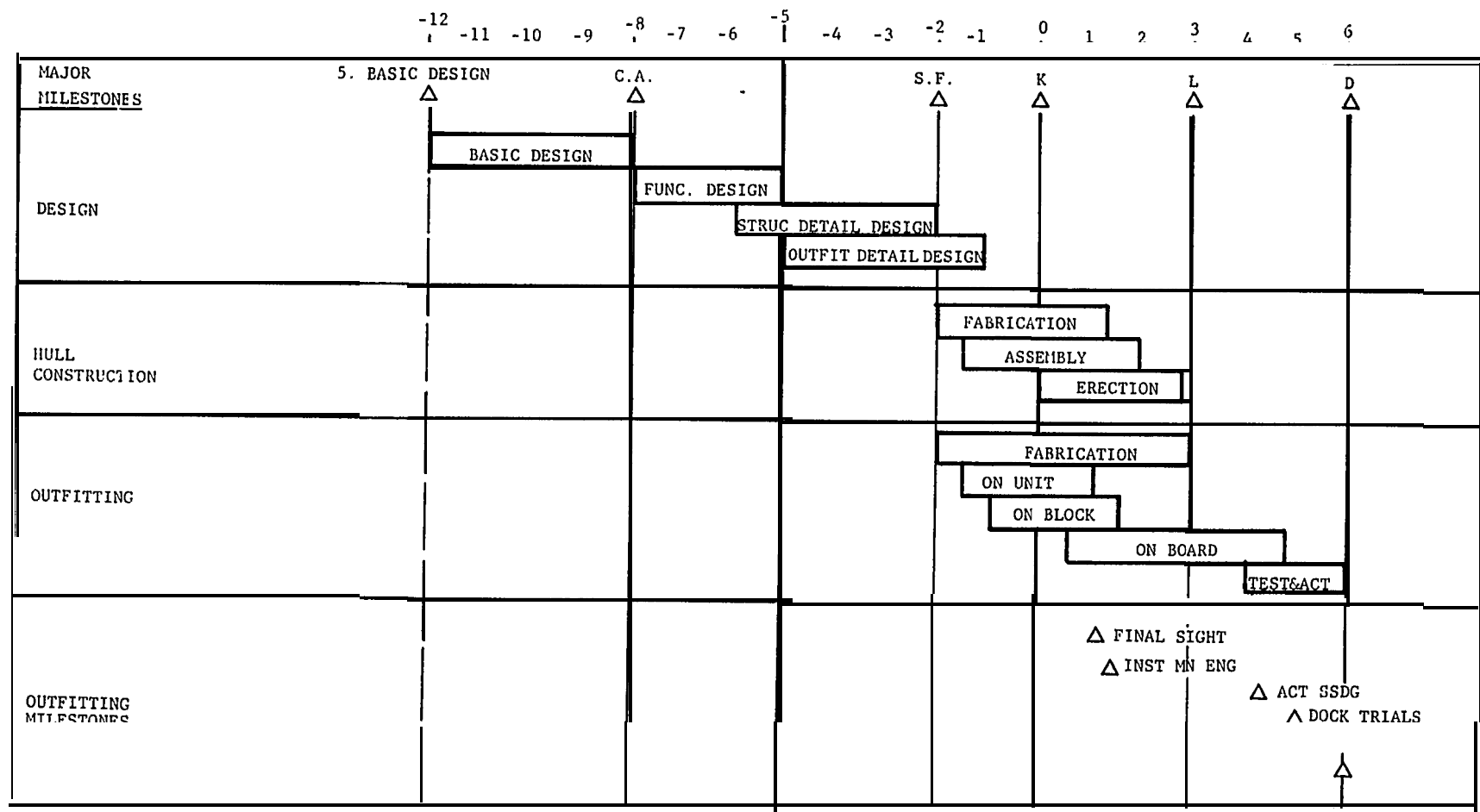
Contract Award to Start Fab	-	6 Months
Start Fab to Keel		
Keel to Launch	-	2 "
Launch to Delivery	-	3 "
		14 Months

Further detail for this schedule is provided in Figure 5.1. A more detailed milestone schedule for a Mitsui bulk carrier is shown in reference 3, page 2-4.

- A typical IHI schedule for a 5200 ton destroyer is shown in Figure 5.2
- In order to achieve the very short shipbuilding periods illustrated in these figures, Japanese shipbuilders have found it necessary to parallel the design, material procurement and production phases as illustrated in Figure 5. 3<sup>2</sup>[2,4].
- Japanese Shipbuilding Schedules are normally Gantt Charts or simple lists. IHI, Kure personnel, indicated that they had tried PERT/CPM Networks and found them too inflexible for the shipbuilding environment. They did, however, indicate that they had used a computer network analyses system (PMS) for the design and production of a floating power and pulp plant for the Amazon River. The reason given for using network analyses on the latter project is the fact that their previous shipbuilding experience did not directly relate and they needed a more detailed analysis to identify critical paths and establish schedules.
- Scheduling and control of both the front end and production phases are simplified by the common zone or area orientation of the design, planning, scheduling, labor/material control and production.

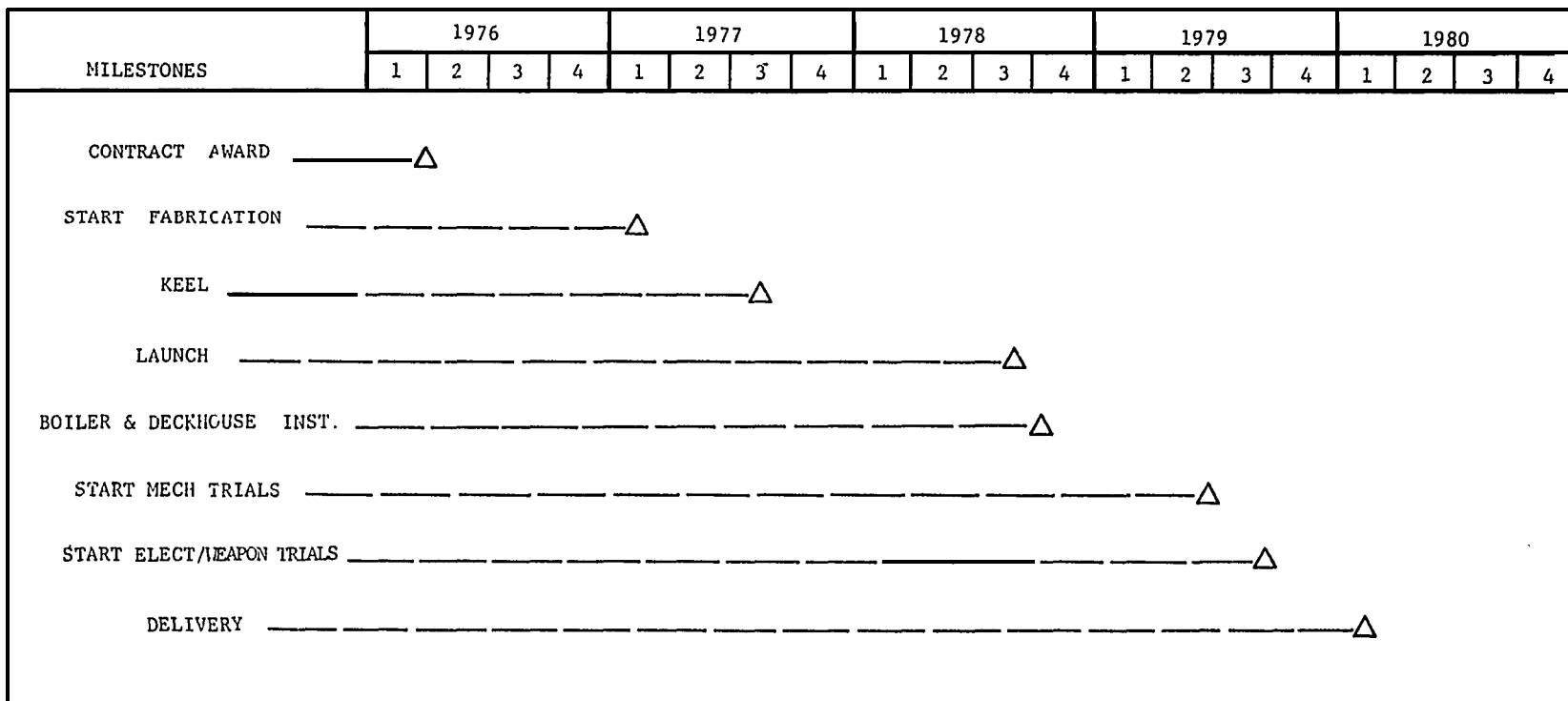
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<sup>2</sup>Parallel design, material procurement and production is more readily scheduled and controlled with a product-oriented detailed design.



NOTES: 3. TYPICAL WITH MINOR ADJUSTMENTS FOR A NON-STANDARD CARGO, BULK, CONTAINER, OR RO/RO SHIP.  
 4. BASED UPON REF. 3 AND NOTES ON IHI

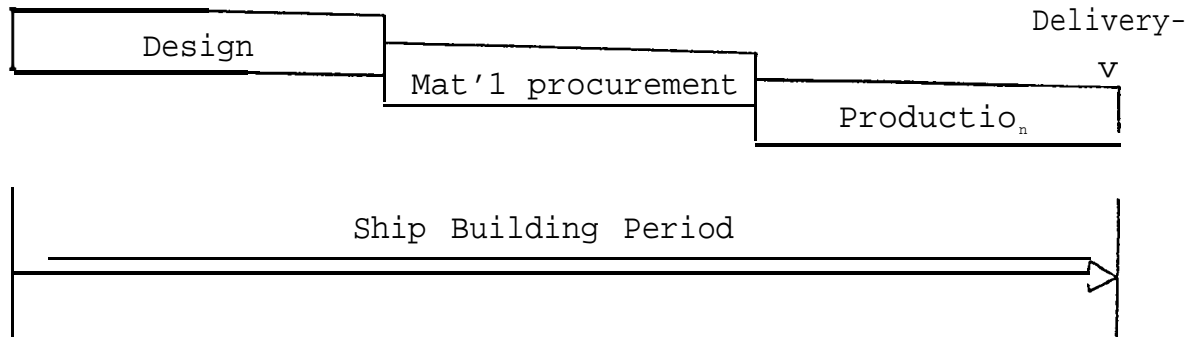
FIGURE 5.1 - TYPICAL JAPANESE MILESTONE SCHEDULE FOR COMMERCIAL CONSTRUCTION<sup>3,4</sup>



NOTES: 5 - TYPICAL FOR A FIRST OF CLASS HAVING SIMILAR MACHINERY TO A PREVIOUS CLASS  
 6 - LIMITED ON UNIT AND EXTENSIVE BLOCK OUTFITTING WAS USED ON 1ST HULL  
 7 - BASED UPON IHI NOTES ON TOKYO D.D.H. CONSTRUCTION

FIGURE 5.2 - TYPICAL IHI SCHEDULE FOR A 5200 TON DESTROYER

### Conventional Outfitting



### Zone Outfitting

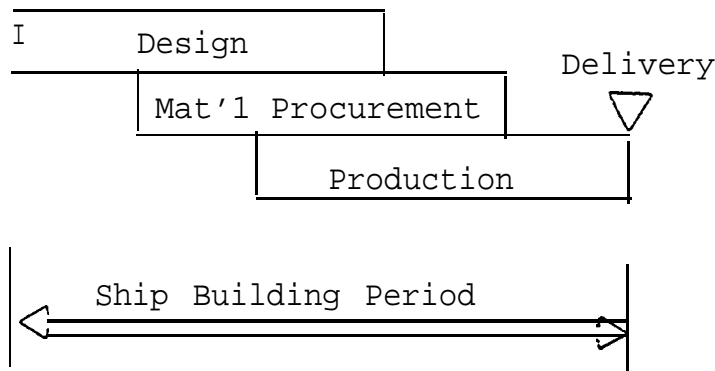


Figure 5.3

- Although schedules are simpler and in less detail than U.S. practice, control appears excellent in all areas.
- Additional explanations and examples of Japanese Ship-building Schedules can be found in Reference [3], pages 5-4 to 5-11, and in Reference [4], pages 30-33.

## 5.2 Organization of Work

- The organization of work has been further simplified by the product or zone orientation of both the design and production organizations. A typical product or zone breakdown used with minor modifications in both design and production is as follows:
  - Hull Construction (Hull Fabrication, Assembly and Erection)
  - Accommodation Outfitting (Outfitting of Accommodation Spaces)

- Deck Outfitting (Outfitting of Cargo and Deck Areas)
- Machinery Outfitting (Outfitting of Machinery Spaces)
- Electrical Outfitting (All Electrical Outfitting)

This is shown-for commercial shipbuilding in Figures 5.4 and 5.5. The production outfitting division organization is modified for naval construction as shown in Figure 5.6.

- All production work in the fabrication, assembly/pre-outfit, and on board outfit phases has been organized by zone or area through the use of working plans and material lists (pallet lists). Systems take precedence over zones at the time of shipboard testing.

The Pallet (workpackage) is zone or area oriented in order to simplify scheduling and control of labor and material. This is illustrated by Figure 5.7.

- A similar approach has been taken by IHI Tokyo in their construction of the DDH, a 5200 Ton Twin Screw Destroyer.
- The following categories have been developed by IHI to assist in defining pallet breakdowns.
  1. On-block\*outfitting after a steel block is turned over for material preassembled into a Unit.<sup>9</sup>
  2. On-block outfitting for material pre-assembled into a unit.
  3. On-board outfitting for material pre-assembled into a unit.
  4. On-block outfitting for material to be installed piece by piece.
  5. On-block outfitting after a steel block is turned over for material to be installed piece by piece.
  6. On-board outfitting prior to an area being closed in by an overhead block.
  7. On-board outfitting by zone or area prior to system tests (or other key events such as launch, trials. etc.).
  8. On-board outfitting prior to launch.
  9. On-board outfitting after launch.
  10. On board outfitting general category for items such as spare parts and touch up.

---

<sup>8</sup>The installation of outfit components, which could include a unit; onto a hull structural assembly or block prior to its erection.

<sup>9</sup>An assembled interior product consisting of manufactured and purchased components not including any hull structure.

<sup>10</sup>Installation of any remaining outfit material and the connection of units and/or outfitted blocks.

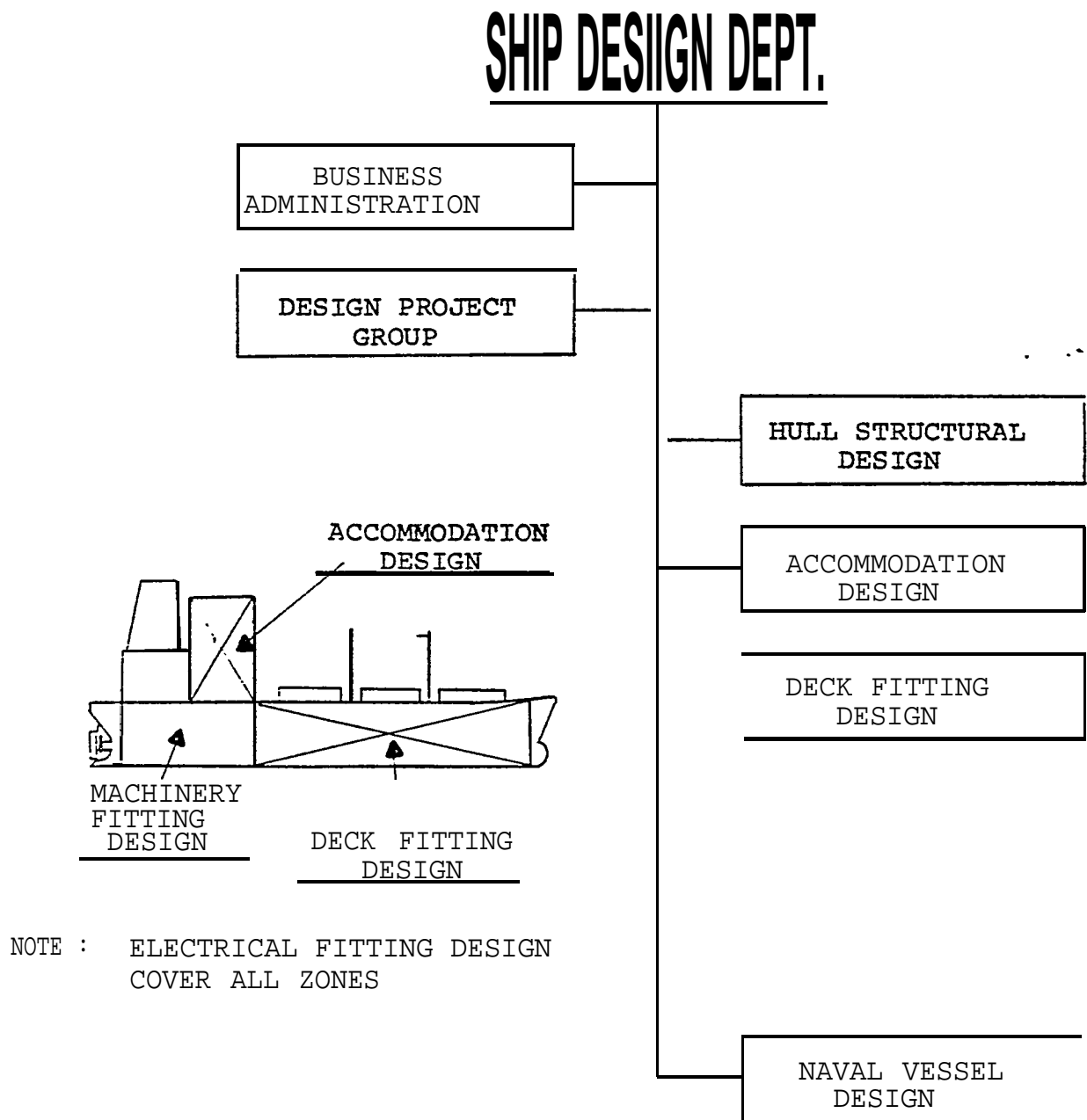


FIGURE 5.4 - IHI KURE Organization of Design Division





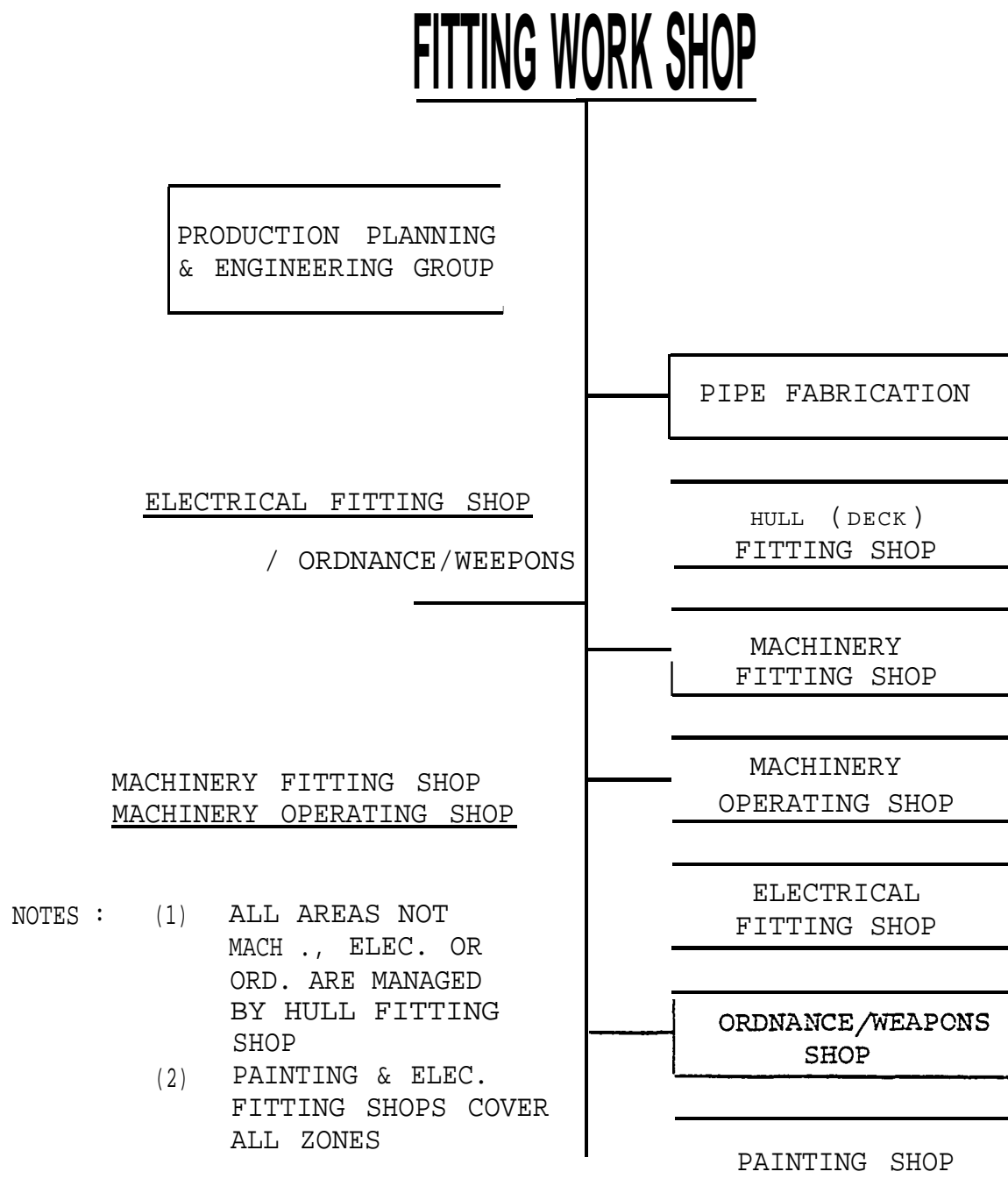
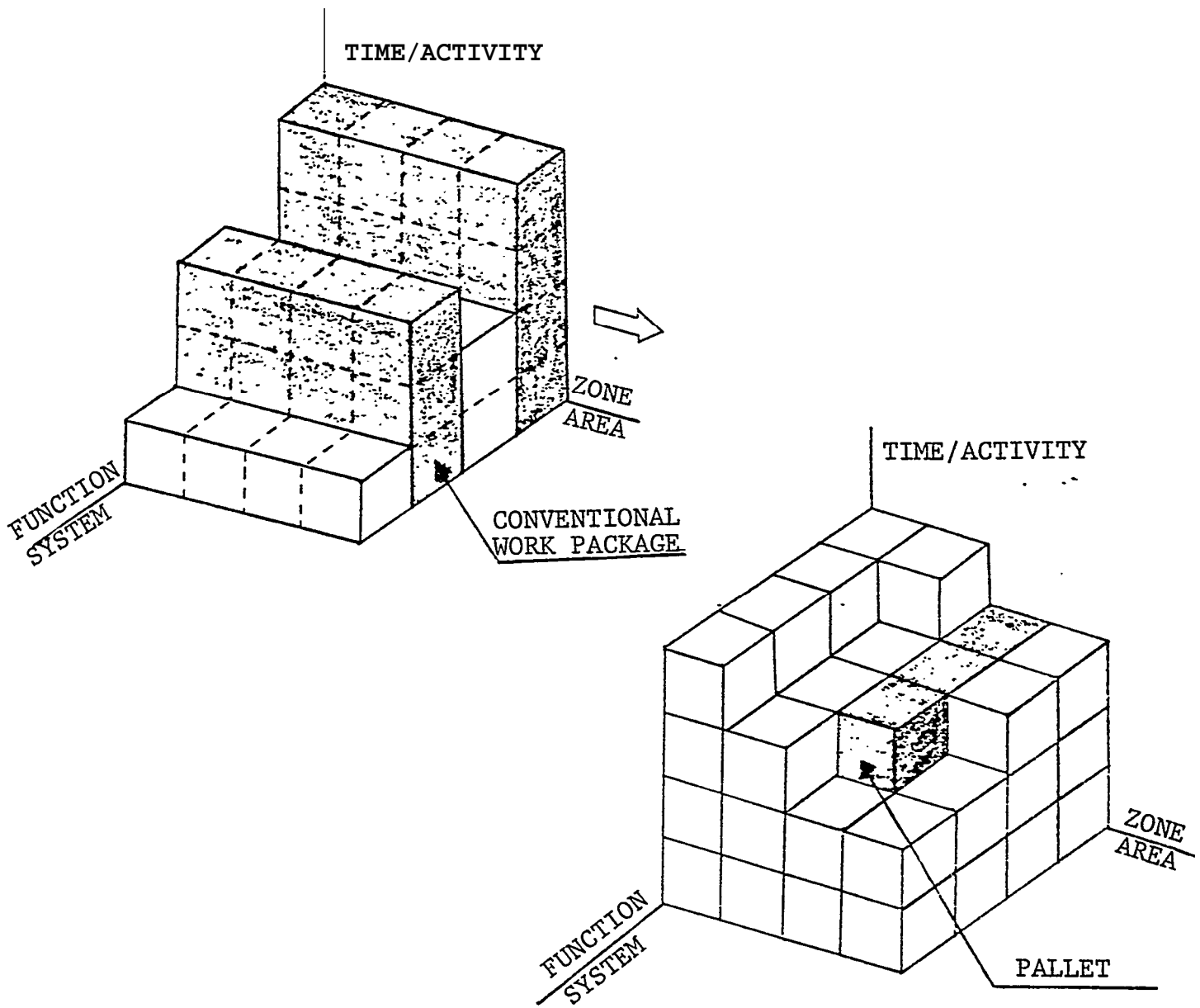


FIGURE 5.6 - IHI TOKYO - Organization of Outfitting Division for Naval Vessels



#### CONVENTIONAL OUTFITTING

Conventional system oriented work packages cross multiple zones (areas) and times (activities) giving limited control

#### ZONE OUTFITTING

Zone oriented pallets cross multiple systems but align directly to production work being accomplished by zone (area) and time (activity) thus giving good control.

FIGURE 5.7 - Concept of Palleting or Zone Outfitting

- The organization of outfit in the engine room lower level of a typical diesel machinery space is illustrated as follows:
  - 5 Structural Blocks
  - 3 to 4 Pipe Units
  - 10 -12 Machinery Units
- The number of Pallets or MLFs (Pallet Material Lists) for typical IHI standard vessels are shown in Figure 5.8.
- The transition from zone or area construction to system completion in the piping area takes place at testing. The testing of commercial ship piping systems is normally done by zone as a result of the zone orientation of the outfitting crafts and to support schedule completion of individual zones.
- Outfit parts, other than piping, are subcontracted for fabrication locally thus simplifying internal control.

### 5.3 Design Approach

- In Japanese Shipyards the design effort is divided into four stages:
  1. Basic Design - Preliminary design calculations, general arrangement, machinery arrangement, midship section, scantling plans, and system diagrams. (Performed in the Tokyo Head Office.) It is more complete than U.S. practice.
  2. Functional Design- The completion of key drawings such as arrangements, system diagrams, structural scantling plans, etc.
  3. Detail Design - The conversion of functional design information into zone or area oriented structural and outfit working drawings.
  4. Work Instruction Design - Structural lofting, pipe sketching, and the development of other detail fabrication sketches required to fabricate or purchase small subassemblies.

KIND OF VESSEL	ZONE	ON BLOCK	ASS. UNIT	ERECT UNIT	ERECT	TOTAL	TOTAL UNITS
FREEDOM MK-11 15,000 TON MPC	ACC	34			408	442	0
	HULL OUTFIT	132	56	8	109	305	64
	MACH	66	30	49	107	252	79
	ELECT	90		44	82	216	44
	TOTAL.	322	86	101	706	1215	187
FREEDOM 17,000 TON MPC	ACC	24			285	309	
	HULL OUTFIT	185		1	187	373	1
	MACH	32	17	45	227	321	62
	ELECT	11		19	52	82	19
	TOTAL	252	17	65	751	1085	82
FORTUNE 20,000 TON MPC	ACC	69			159	228	
	HULL OUTFIT	138		2	63	203	
	MACH	35		81	110	226	
	ELECT	33			88	121	
	TOTAL-	275		83	420	778	
B.C. 60,000 TON	ACC	87		2	239	323	2
	HULL OUTFIT	431	116	33	106	636	149
	MACH	32	18	78	144	272	96
	ELECT	46			173	219	
	TOTAL	596	134	113	662	1505	247
D.C. 168,000 TON	ACC	83		5	262	350	5
	HULL OUTFIT	515	94	44	11.2	765	138
	MACH	55	23	93	171	342	116
	ELECT	49			201	250	
	TOTAL	702	117	142	746	1707	259
VLCC 250,000 TON	ACC	58	18	5	234	315	23
	HULL OUTFIT	532	136	101	151	920	237
	MACH	84	5	106	208	403	111
	ELECT	40			196	236	
	TOTAL	714	159	212	789	1874	371
VLCC 250,000 TON	ACC	96	19	17	275	407	36
	HULL OUTFIT	487	124	83	139	833	207
	MACH	88	32	115	190	425	147
	ELECT	85			223	308	
	TOTAL	756	175	215	827	1973	390

\*Material list for Pallets/Work Packages

FIGURE 5.8 - No. of Pallets or MFL's<sup>8</sup> for IHI Standard Vessels

Functional, detail, and work instruction designs are normally accomplished in the yard design office.

- Outfitting working plan development has been streamlined through the use of "Composite Outfit Arrangement Drawings". The use of the Composite Outfit Arrangement Plan is a key element in the reduced working plan development time achieved by Japanese Yards vs. U.S. practice. This is illustrated by a Flow Chart of Outfitting Working Plan Development, Figure 5.9.
- A description of Outfitting Working Drawings or Composite Outfit Arrangement Drawings is as follows:
  - Engine Room Lower Level - Drawings include foundations; piping; grating framework, plating, and handrails; piping supports; and ladders.
  - -Deck Piping - Drawings include piping; rails; ladders; deck fittings; piping supports; and foundation installation.
  - Forecastle Deck - Drawings include deck fittings; equipment and foundation installation; grating framework, plating and handrails; piping; and piping supports.
  - Accommodations - Three drawings were used; a) piping, ventilation, ladders, equipment and foundation installation; b) joiner installation and c) electrical installation.
- The outfitting composite drawings reviewed at all the shipyards were not sophisticated drawings. The piping was shown as one line although the flanges appeared to be shown double line. The composite drawings did include elevations, sections and details and the drawings were coded with symbols or by shading to indicate the installation stage, i.e. on unit, on block, or on board.
- Piping and other system diagrams are developed in schematic form by deck level similar to U.S. practice. Piping diagrams are complete in all respects and along with the machinery arrangements are the only piping drawings submitted for agency approval. The piping diagrams are used in conjunction with machinery arrangements to determine the pipe lengths for the purpose of sizing and material calculations.

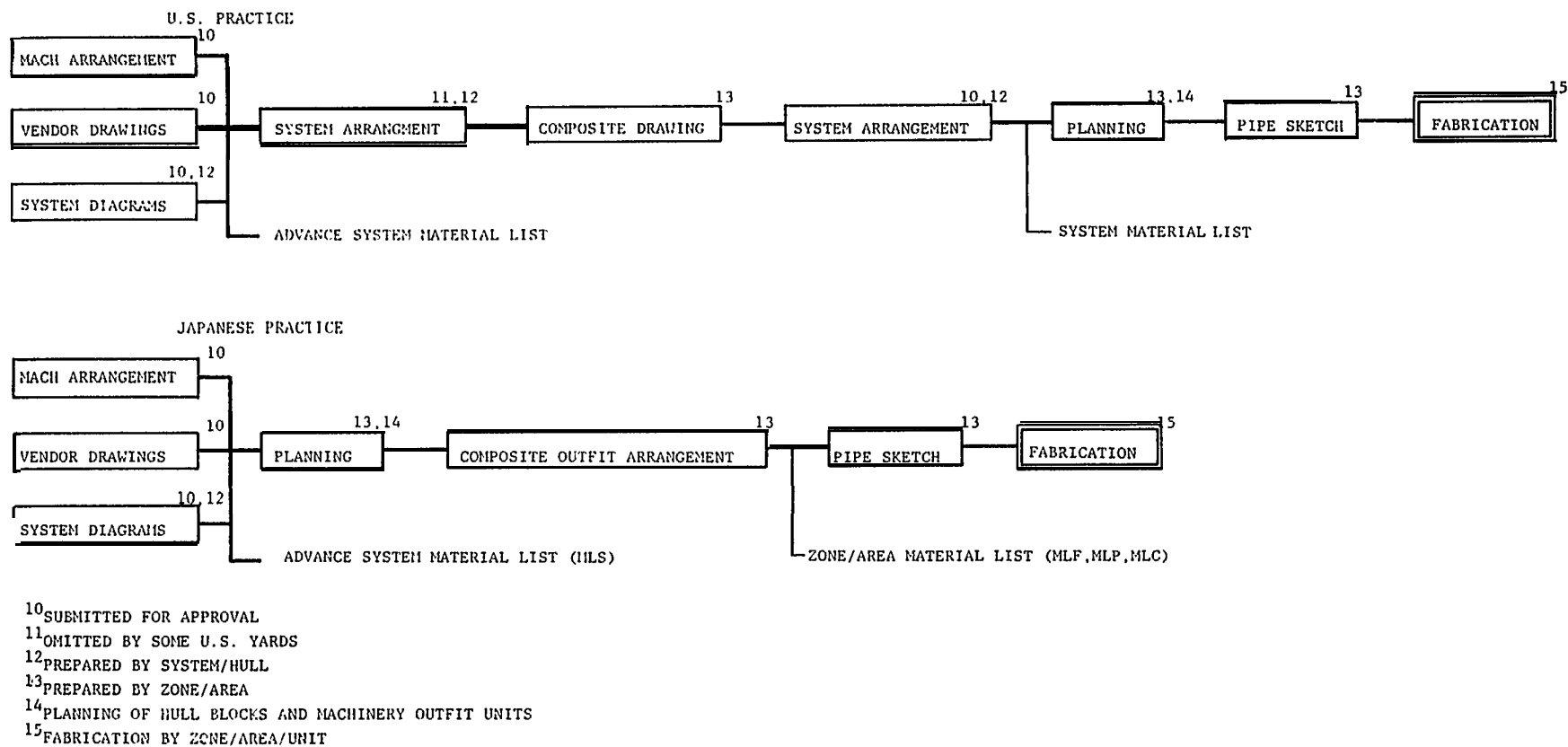


FIGURE 5.9 - FLOW CHART OF OUTFIT WORKING PLAN DEVELOPMENT  
 U.S. VS. JAPANESE PRACTICE

- Both functional and working plan development are greatly assisted through the use of comprehensive standards and extensive experience on previous vessels.
- Typical structural working plans include deck, side shell, web frames, etc. for the complete block or for a group of similar blocks. Structural working plans do not include foundations which are issued on a separate block plan by area or zone.
- Material is ordered in progressive stages throughout the functional design, detail design, and work instruction design phases in order to suit material lead times. Long lead material is ordered by the Tokyo office during the basic design phase. This is illustrated by Figure 5.10.
- Ž The design is developed based upon intensive planning and production input early in the design process. This is also illustrated by Figure 5.10.
- The working plans and material lists (Pallet Lists) provide a common documentation for design, planning, scheduling, labor/material control and production.
- Additional explanations and illustrations of the Japanese design process can be found in reference 3. pages 3-1 to 3-8 and in reference 4 pages 7 through 11.

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Documented standards or guidance data for use in the areas of functional design, detail design, planning production and quality control.

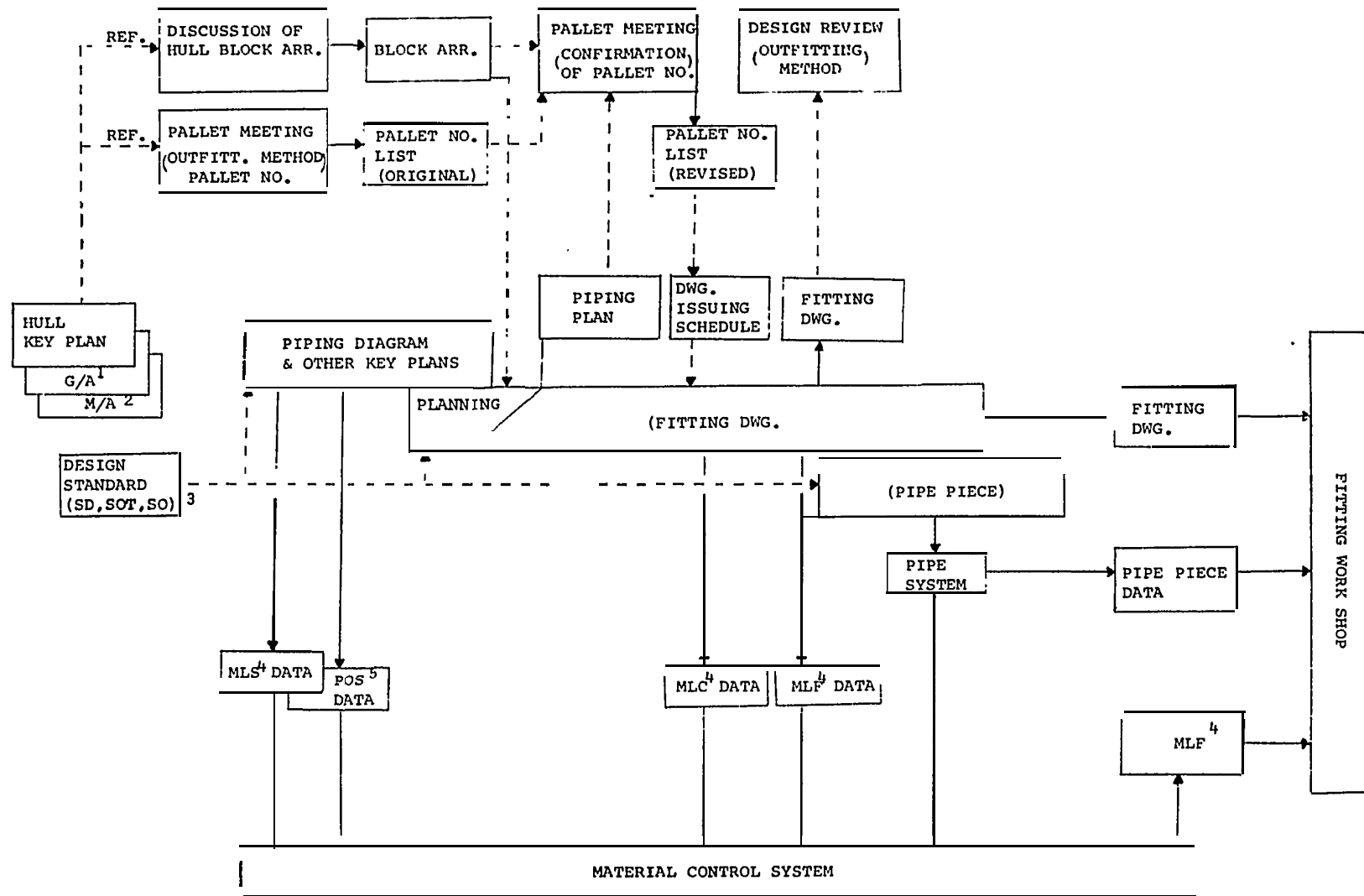


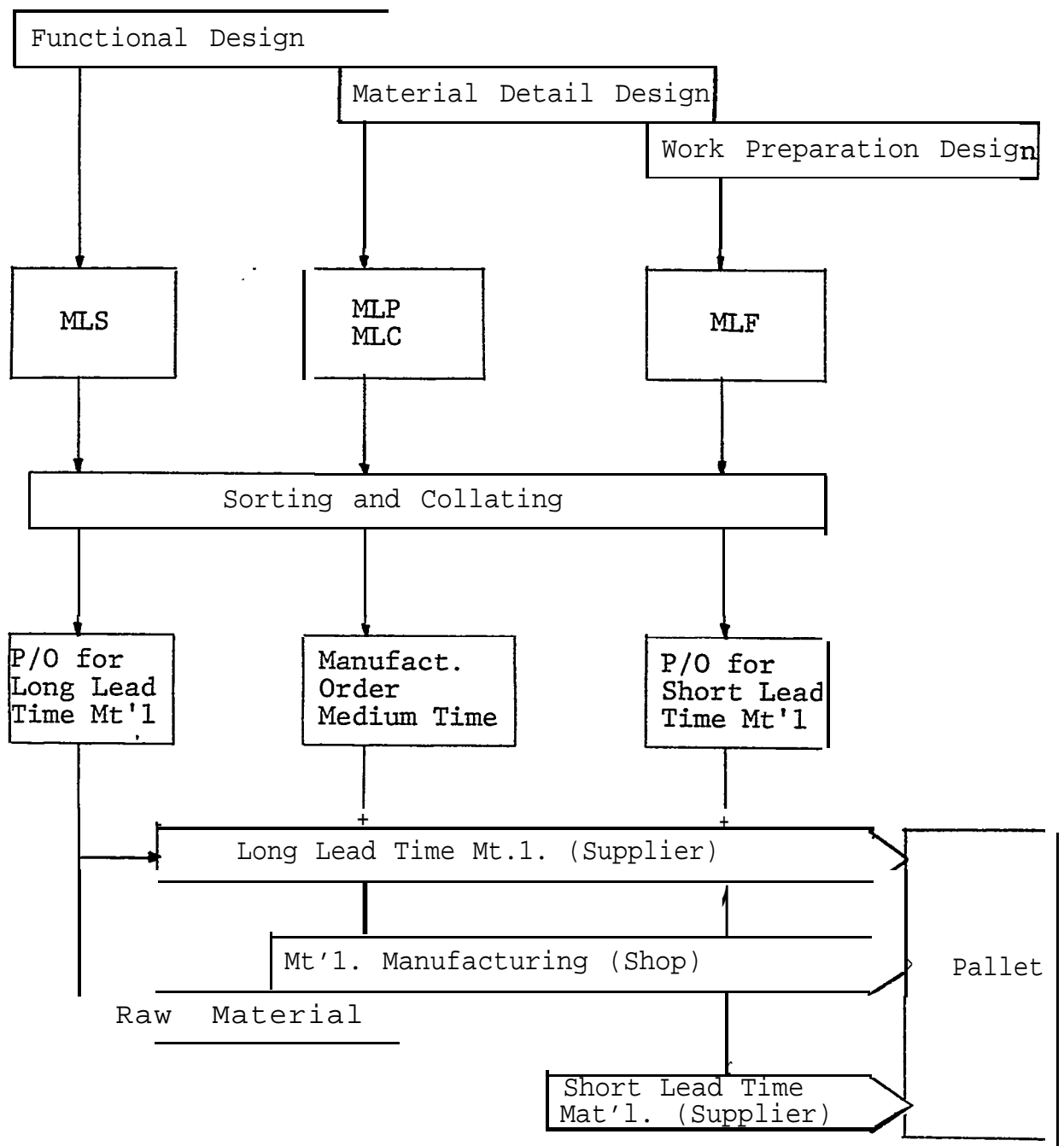
FIGURE 5-10 - Outline Process of Pallet Design - IHI[4]

- NOTES: 1 - General Arrangement  
2 - Machinery Arrangement  
3 - See Figure 5.12  
4 - See Figure 5.11  
5 - Purchase Order Specification



## 5.4 Material Definition and Procurement

- Requirements for shortened periods between contract award and delivery dictate an overlap of design, material definition and procurement, and Production. Mitsui personnel indicated that on new ship design work, nearly all material was defined at the point at which approximately 30% of the total design man-hours had been expended.
- Materials are defined and procured early thru the use of a unique series of standard classifications of material (IHI) and by utilization of the concept of purchasing zones used in design to schedule accelerated procurement.
- The relationships between design, the material lists and procurement is shown in Figure 5.11 along with a definition of material classification terms.
- The use of these concepts to organize material requirements so that purchase and manufacturing orders can be placed as early as possible is a key element of high Japanese productivity.
- See reference 4 pages 21 through 24 for more details concerning specifying and procuring materials through the use of these standard classifications. These concepts are explained in detail in reference 2.



- Notes :
- MLS Material List by (ship's functional) System (by purchasing zone)
  - MLP Material List for (manufacture of) Pipe (pieces)
  - MLC Material List for (manufacture of) Components (other than pipe) (this is a list of subcontractor fabricated materials)
  - MLF Material List for Fittings (per pallet, i.e., per work zone per work stage)

Figure 5.11 Relationships Between Design, Material Lists and Procurement

## 5.5 Shipbuilding Standards and Modules

- Both IHI and Mitsui have developed extensive standards for use in functional design, detail design, planning, production and quality control. Figure 5.12 provides a classification of IHI standards. Figure 5.13 lists the numbers of various IHI standards.
- According to IHI, Kure personnel, standards have been developed to reflect the highest quality based on new requirements and reflecting the experience of the past. The use of standards is sold to the owner, during technical negotiations prior to contract award, based on the principals of proven service experience, reduced delivery time and reduced cost.
- The use of standards and modules in this manner is a key element in the significantly reduced design and production costs and schedules achieved by Japanese Shipyards vs. U.S. **practice.**[5]<sup>16</sup>
- IHI's design approach appears heavily oriented to the use of design standards which have been developed based on Standard ship design. See Figure 5.8 for examples of standard IHI designs. Although these design standards are based on standard ship designs, they have been developed with the idea of solving a range of problems versus solving the specific design problems presented by the ship being designed. Mitsui, on the other hand, bases their designs on previous ships having similar engine types and power ranges. Neither IHI nor Mitsui appear to have a totally comprehensive documented set of standards covering all ship types. Standards for tanker and bulk ships appear to be very thoroughly developed, while standards for liner ships are less completely developed.
- Both IHI and Mitsui have single main engine vendors for both low speed and medium speed diesel. IHI manufactures the low speed Sulzer and medium speed Pielstik engines while Mitsui manufactures the low speed B&W and a medium speed Mitsui engines.
- Design and material standards start at the level of individual components and pieces of raw material and include progressive tiers to the level of standard machinery arrangement modules and system diagrams for various standard ships and various sizes of standard steam or diesel power plants.

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<sup>16</sup>Reference 5 by Y. Ichinose. IHI contains a detailed description of IHI standards and modules.

- The design of system modules using IHI functional design standards is illustrated in Figure 5.14. In this case, the design standards have allowed for alternative system capabilities and the designer selects from these alternatives to create the functional and working drawings for a new ship design.
- An example of machinery component standards is illustrated by Figure 5.15. These standards appear to have been developed to a range of requirements instead of being designed around a specific ship type.

Functional design standards for a 60,000 ton bulk carrier **engine room design**<sup>17</sup> included the following:

- Engine Room arrangement based on a single engine type with alternative number of cylinders.
- Machinery arrangement including plan, elevation and section.
- A list of key equipment including alternate vendors except for the main engine.
- All system diagrams.
- An arrangement of machinery units or outfit packages.
- Machinery module designs.
- Parts lists for individual systems and machinery modules

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<sup>17</sup>The majority of machinery units or outfit packages shown for this design were based on standard machinery modules which are system oriented. Example, lube oil purification, fuel oil treatment, jacket water heat exchangers, etc.

- IHI personnel indicated that they have previously forwarded to Bath Iron Works, as the MARAD Standards Program Manager, a proposal for technical assistance in the area of standards development. This proposal should be carefully reviewed, although, at this point, Mr. Hamada of IHI, indicates that the question of selling IHI's standards or assistance in standards development is a question that requires complete review by IHI top management.
- Mitsui design standards, in the form of design manuals and design check lists, were reviewed. These design standards provide substantial guidance to designers in the form of partial system diagrams, tables or graphs simplifying engineering calculations, check lists of items required to properly complete functional or working drawings, check lists of items required to ensure reduced costs in the production area and check lists, based on experience, of items causing either production problems or problems in the guarantee area.
- This approach to standards has provided Japanese shipyards a formalized way of documenting their experience and of developing new design or production procedures documented in a manner that they can be modified as required to suit new owner or service requirements.
- Additional explanation and examples of Japanese practice in the area of shipbuilding standards can be found in Reference 3, pages 3-7 to 3-16, and Reference 4 pages 14 through 19.
- Although IHI appears to have moved further in developing comprehensive shipbuilding standards, both Mitsui and IHI should be considered as potential subcontractors for the development of a comprehensive standards program.

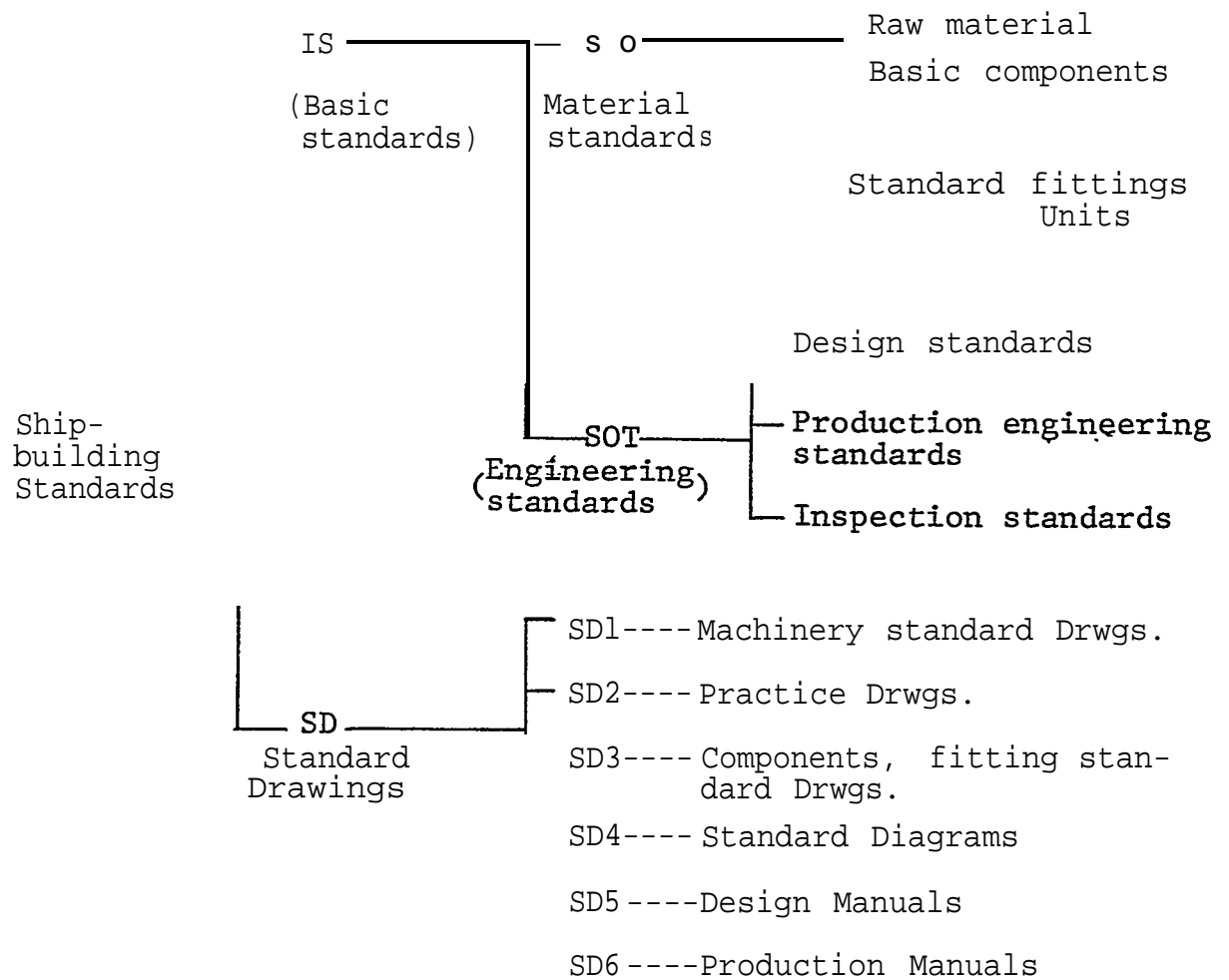


FIGURE 5.12 - Classification of Standards (IHI)

cl classification of Standards				Nos.
IS	SO	Material standards	Common components	600
			Hull fittings	600
			Machinery fittings	200
			Electric fittings	200
		Sub-total		
	SOT	Design standards		1,100
		Production eng. standards		100
		Inspection standards		200
		Sub-total		
SD	Machinery drawings SD1			1,200
	Component and fitting standard dwgs			350
	Other guidance drawings			350
	Sub-total			1,900
Grand total				4,900

FIGURE 5.13 - Numbers of IHI Standards

<sup>18</sup>SD1 are standards where a change must be the result of a mutual agreement between IHI and a vendor or subcontractor.

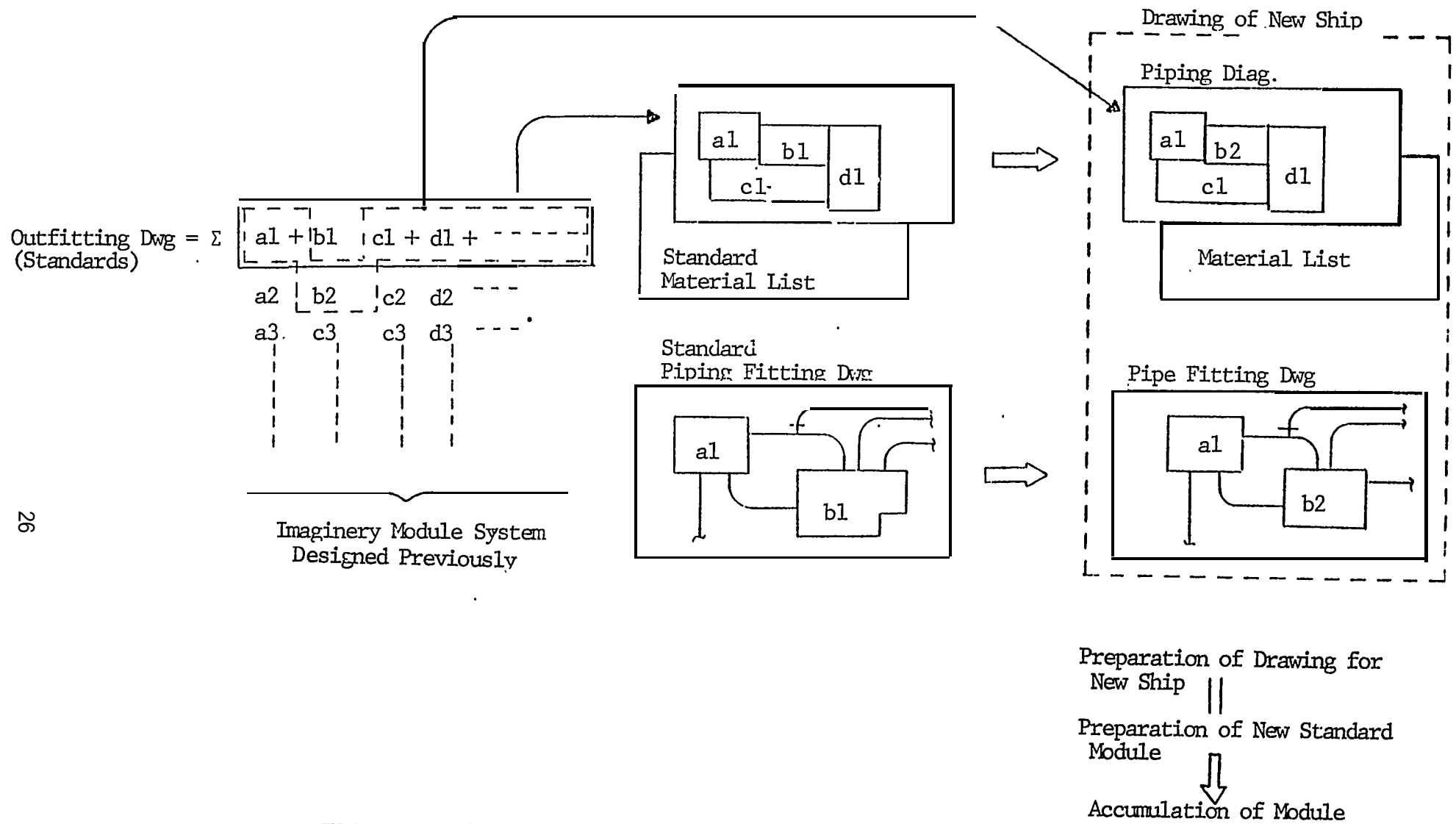


FIGURE 5.14 - Flow Chart Of System Module Design (IHI)



Drain Pump (Large Size)					Mach No.	M O 2 3	
					Type	V E C	
Cargo Pump Cap.	m3/h x m	3,500x125	4,000X125	3,500X150 4,000X150	4,000X150	4, 500X150	5,000X150
Cargo Pump Sets	KWxrpm	3	3	4		4	4
Capacity	m3/h x m	70 x 90	80 X 90	90 x 95	110 x 95	130 x 95	70 x 100
Model No.		EVZ 100	1wz 130			J3VZ130-2	EVZ-130
Stand. Drwg. No.	SDX	140011360A	440011380			440011390	440011380
Motor capacity	KWxrpm	37 x 1800	45 x 1,800		55 x 1,800	75 x 1,800	45 x 1,800
Motor Model No.							
Capacity range	m3/h x m	56 - 70 x 90	76 - 100 x 90	78 - 95 x 95	96 - 110 x 95	118 - 130 x 95	66 - 85 - 100
Weight	Pump	t					
	Motor	t					
Maker B	Model No.	200 x 100- 2YCSE-A	250 x 125 - 2VCDS - A			300 x 150- 2VCDS-A	250 x 125- 2VCDS-A
	Stand. Drwg. No.	S D I	440021730A	440021740A		440021390	440021740
	Motor Capacity	KWxrpm	37 x 1,800	45 x 1,800		55 x 1,800	75 x 1,800
	Motor Model No.						
	Capacity range	m3/h x m	51 - 70 x 90	80 - 100 x 90	95 x 95	91 - 110 x 95	130 - 140 x 95
	Weight	Pump	t				
		Motor	t				

FIGURE 5.15 - Sample IHI Machinery Component Standard

## 5,6 Outfitting Approach

- Outfit Planning is a term used to describe the allocation of resources for the installation of components other than hull structure in a ship. Methods applied in Japanese shipyards have produced such benefits as [2]:
  - (1) Improved safety
  - (2) Reduced cost
  - (3) Better quality
  - (4) Shorter periods between contract award and delivery
  - (5) Adherence to schedules
- Three key features of the methodology are that the outfit design and planning functions are intimately linked, that they are linked because their principal product is the definition of modular, sometimes multisystem units called "interim products", and that the design and planning of these units is controlled largely on the basis of geographical regions in the ship called zones.
- Zone outfitting as developed by Japanese Shipyards is broken into three basic stages listed by order of priority.
  - On-unit  
The assembly of an interim product consisting of manufactured and purchased components not including any hull structure.
  - On-block  
The installation of outfit components, which could include a unit, onto a hull structural assembly or block prior to its erection.
  - On-board  
Installation of any remaining outfit material and the connection of units and/or outfitted blocks
- On-unit outfitting has the highest priority because of its minimal impact on hull construction schedules, and, because it is performed in shops which provide ideal working conditions and promote higher productivity.
- IHI and Mitsui stated the following man hour savings for on unit and on block preoutfit:
  - on unit. vs. on board = 70% savings
  - on block vs. on board = 30% savings

- A high degree of on-unit outfitting was observed in all shipyards performing commercial construction.
- Pictures of the DDH construction viewed in IHI Tokyo indicated limited use of on unit outfitting and extensive on block outfitting.
- The primary emphasis of Japanese shipbuilders is on maximizing the on-unit outfit function. The key advantage of this approach are:
  - (1) increased outfit levels
  - (2) reduced construction time due to parallel construction of structure and outfit.
  - (3) reduced interface of outfit and structural trades during steel assembly.
  - (4) improved sequencing and control of work. Earlier application of labor and material.

## 5.7 Dimensional Control

- Structural dimensional control was very advanced in the yards visited. Midship units were fabricated neat with no stock, and most bow and stern blocks were cut neat at assembly.
- The dimensional control approach was described as the monitoring and control of each fabrication, sub-assembly and assembly operation based upon worker and supervisory quality control inspection and documentation.
- Dimensional control standards were stated to be based upon experience and statistical projections of cumulative errors.
- This system is considered key in their low assembly and erection manhours as fit up was excellent and rework was minimal.

## 5.8 Steel Construction

- The block breakdown is defined very early in the contract and is a key input into the development of functional and detail design.
- The steel plate and shape storage yards are very small compared to U.S. practice. Steel is normally delivered only one or two days prior to fabrication.
- Steel fabrication and assembly shops are large and very well laid out. The area of steel assembly shops to ship erection area is greater than U.S. practice.
- Steel plates were typically laid out using optical projection in the electro-photo marking process (EPM). After layout, the plates were transferred to a cutting conveyor where they were cut to shape manually. Limited use of numerical control cutting machines was observed.
- Steel shapes were laid out and burned to shape manually while moving on conveyors. The burning conveyors for plates and shapes were similar to those used in the U.S. The use of conveyors in these applications eliminated crane and handling time.
- Limited use of plate rolls and presses was observed. Heat line bending of plates was observed in all shipyards visited except IHI Aioi [6].
- Subassembly areas were large and well laid out. The subassembly of small floors and web frames was typically accomplished on a moving conveyor or on raised post mocks. The subassemblies for tanker web frames included staging clips, small lifting pads for use in assembly, and handgrabs or ladders for use during assembly and erection.
- IHI has a preference for the "egg crate" assembly method because with a panel line:
  - (1) There are more trim and alignment problems with stiffeners.
  - (2) More facility is required.
  - (3) Automatic fillet welders are a bottleneck
- Ž Directly after the flame planing or cutting of large plates to size, they were joined together and automatic welded with one side welding to form plate blankets.

- After welding of the grid assembly, it was joined to the flat plate blanket to form a complete flat panel block.
- Pin jigs were extensively used for the assembly of curved bilge and side shell units in all shipyards visited.
- All structural blocks were mechanically cleaned and painted prior to erection. Only limited capability for reblasting completed blocks were observed in storage waiting for-erection.
- Midship blocks were fabricated neat with no stock, and most bow and stern blocks were cut neat at final assembly.
- Extensive use was made of jigs throughout the assembly and erection process.
- Permanent access was designed into non-tight structural members to facilitate access during assembly and erection.
- Heat, line fairing, to correct weld distortion, was observed at all subassembly and assembly stages. [6]
- Large capital intensive jigs or work fixtures had been developed for tanker and bulk carrier construction. These include the following:
  - (1) At the Mitsui Chiba Shipyard, the Rotas System was used for the construction of large 60' long by 1400 ton wing tanks. These large blocks were assembled on end, the vertical joints were welded using the electro-slag process, and then the complete block was rotated mechanically for welding in various positions. After the completion of welding, the block was transferred mechanically to the edge of the dock, lowered into the dock, and transferred mechanically to the erection position.
  - (2) At IHI Kure Shipyard, a mechanical devise for rotating large flat panels on end and providing mechanical staging was observed. This system was used to allow complete downhand welding of the web frame to panel connections.
  - (3) At the IHI Kure and Aioi Shipyards, mechanized work units had been developed to provide staging and services as well as mechanical assistance in the erection, fairing, and welding of shell, longitudinal bulkhead, and deck panels on large tanker and bulk carriers.

## 5.9 Welding

- The welding process is defined very early in the contract and is a key input to the development of functional and detail design.
- Subassembly welding was accomplished using gravity rods. The quality of gravity rod welding appeared excellent.
- Flat panel seams were welded using one side submerged arc welding. The one side welding process was used for thicknesses of 9-30 MM (3/8''-1 1/2''). The welding of the three dimensional grids to the flat plate blanket was accomplished using gravity rods.
- Curved panel seams were welded using submerged arc welding against a temporary backing material. The welding of stiffeners and web frames to curved panels was accomplished using gravity rods.
- It appeared that all fitting was accomplished prior to releasing the blocks for welding. In some yards the assembly and welding of flat panel blocks was accomplished on a slowly moving floor conveyor.
- Erection welding was based on the maximum use of automatic and semi-automatic welding processes. Typical processes are as follows:
  - (1) Deck plating was welded with submerged arc using temporary backing.
  - (2) Vertical shell and bulkhead butts were welded using the electro-slag process.
  - (3) Sloping or overhead surfaces were welded using oscillating fluxcore or solid wire MIG against temporary backing.
  - (4) Vertical deck longitudinal were welded using the electro-slag process. Deck longitudinal were flat bar to facilitate this process.
  - (5) Bottom shell, side shell and longitudinal bulkhead stiffeners were welded using the electro-slag process for vertical surfaces and the submerged arc process for horizontal surfaces.
- Mitsui has developed and is testing two versions of welding robots for fully automated fillet welding. A limited amount of information is contained in reference 3.

## 5.10 Computer Aids

- Extensive application of computer aids to all aspects of ship design and construction was evident in all Japanese yards, especially those of IHI and Mitsui. Figure 5.16[7] illustrates the comprehensive coverage of shipbuilding applications at IHI. Refer also to Figure 5.17 which is a list of applications in use at IHI. Figure 5.18 illustrates a similar situation for Mitsui. This situation probably applies as well to NKK [15], but since less information was obtained from them, it cannot be stated.
- A wealth of information on various computer aids was distributed to the U.S. team. This is contained in reference 3, pages 3-17 through 3-26, 4-1 through 4-7, and references 7 through 15. The salient points pertaining to development and use of computer aids are highlighted in the following paragraphs.
- IHI's aim in computerization is rationalization: computerization does not directly imply the act of using computers, but rather is a means of rationalization, by which the quality of the work involved is improved by the process of job review undertaken in applying computers. Since IHI has a significant number of computer applications in place, it has obviously realized significant productivity increases through this process.
- Both IHI and Mitsui have developed computer applications in areas where the return on investment is the greatest. The following paragraphs cite specific examples.
- Both companies have developed and are using applications in the outfitting area that consist of material control (maintenance of material lists, procurement, palletizing) **and outfit scheduling**<sup>19</sup>. The computerization of material lists for procurement and palletizing is considered by IHI to be one of their most important applications.

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<sup>19</sup>IHI utilizes manual scheduling for ship construction, but uses computer scheduling for complex projects such as the floating paper pulp factory (approximately 400 milestones and 30,000 activities).



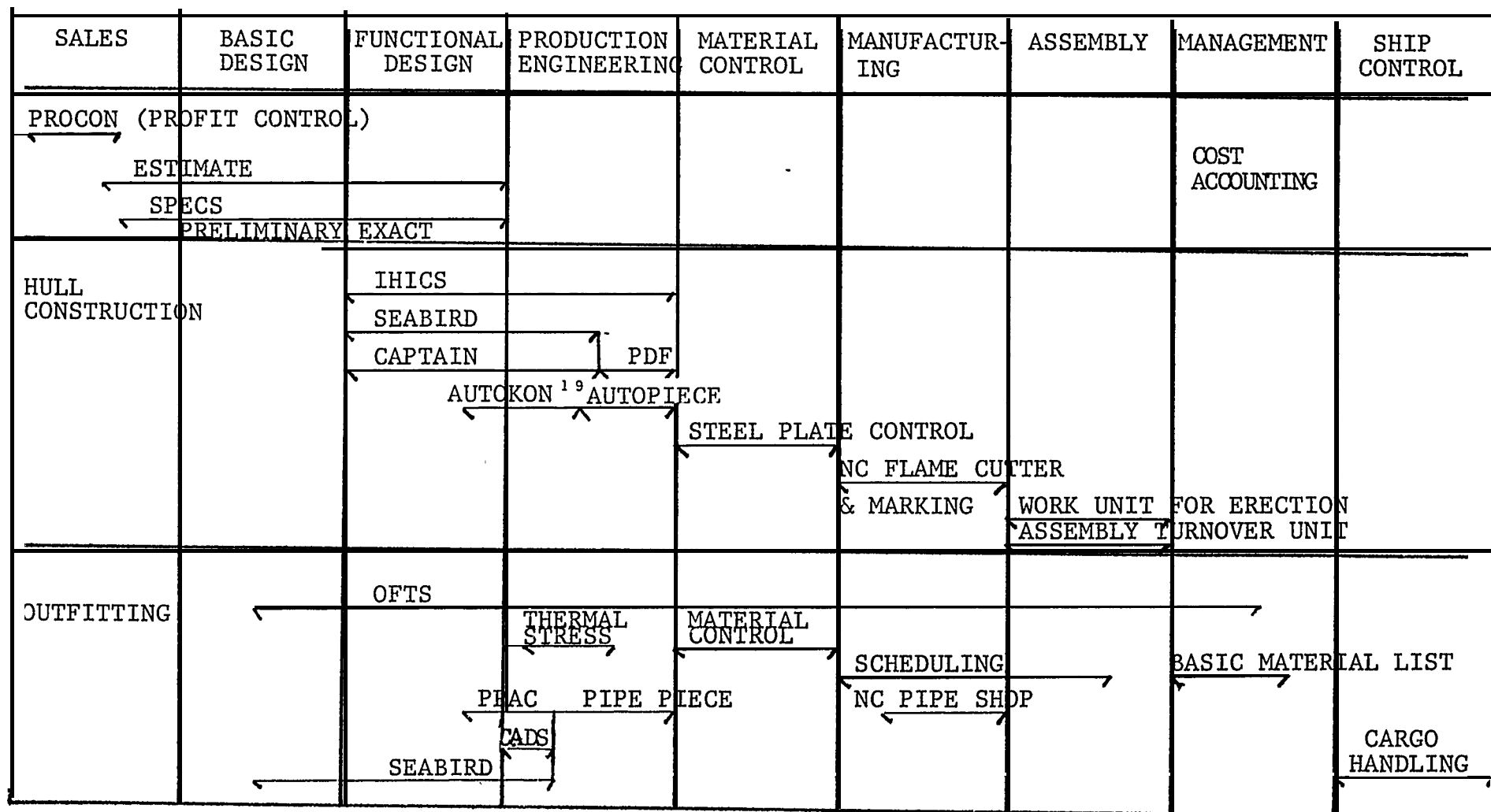


FIGURE 5.16 - Shipbuilding Computer Applications - IHI

<sup>19</sup> The insertion of AUTOKON on this figure is for comparison purposes only. IHI developed AUTOPIECE, an interface program for AUTOKON users to automate piece part production.

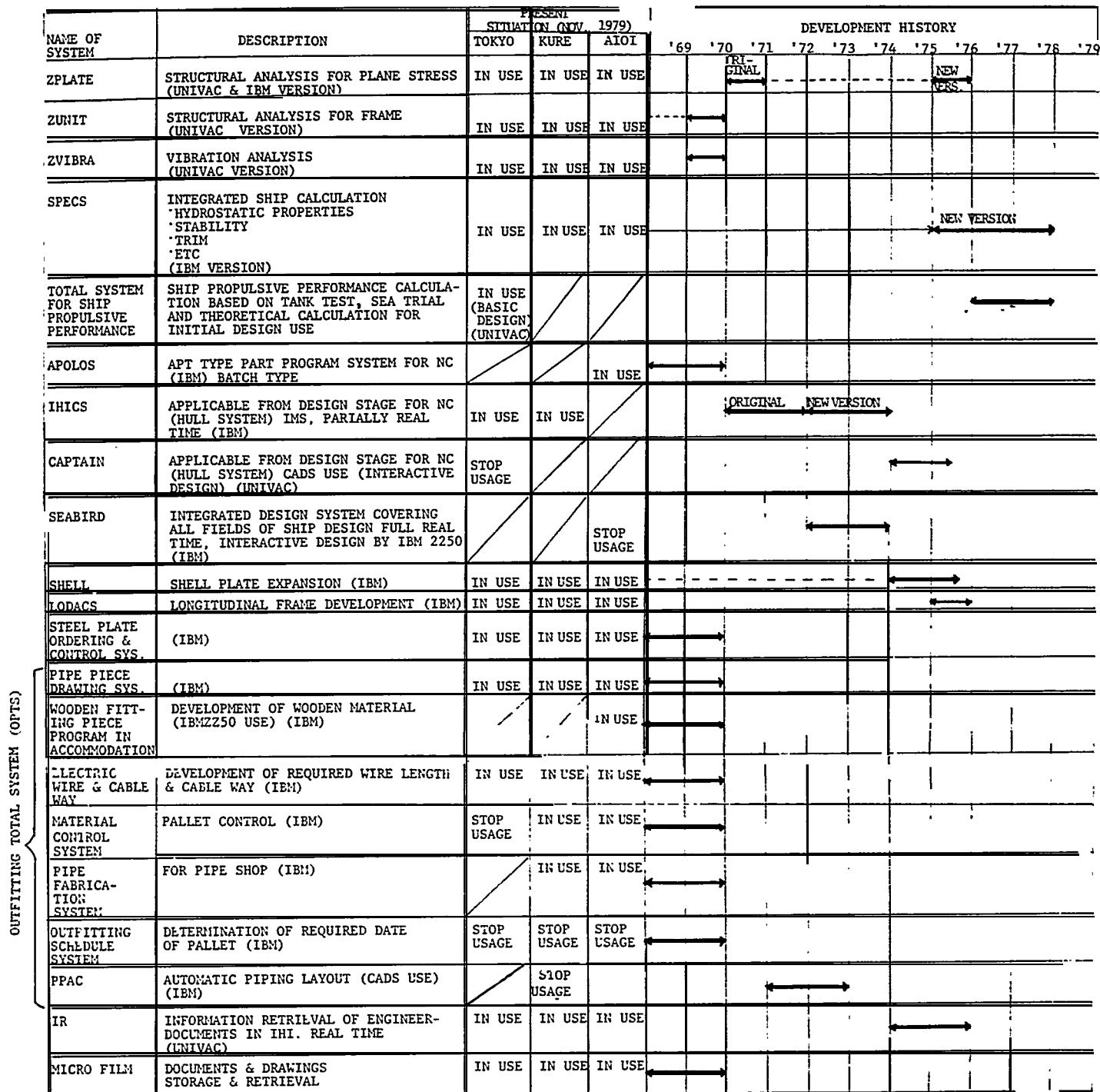


FIGURE 5.17 - MAJOR SHIPBUILDING SOFTWARE SYSTEMS IN IHI

SALES	BASIC DESIGN	FUNCTIONAL DESIGN	PRODUCTION ENGINEERING	MATERIAL CONTROL	MANUFACTURING	ASSEMBLY	MANAGEMENT	SHIP CONTROL
	COST ESTIMATING RULES CALCULATION HYDROSTATICS, HYDRODYNAMICS, STRUCTURAL ANALYSIS FOR SHIPS & OFFSHORE STRUCTURES				DIESEL ENGINE TEST AUTOMATION		COST ACCOUNTING CHECKIN SYSTEM	SHIPS AUTOMATION
HULL CONSTRUCTION		MICAD-H						
			GNC					
			PDL	HULL STEEL MAT'L CONTROL				
OUTFITTING			TOMANO OUTFIT PALLET SYSTEM (TOPS)					
		MAPS	GMAPS, GPS					
				MATERIAL INFORMATION SYSTEM (MIS)				

FIGURE 5.18 - Shipbuilding Computer Applications - Mitsui

- Both IHI and Mitsui have developed and are using systems for automated pipe fabrication (Mitsui Chiba and IHI Aioi). They also use computer applications for piping design and engineering which either interface to their automated pipe shops or produce fabrication instructions (pipe piece drawing and material lists) for manual or semiautomated pipe fabrication. Their systems also produce pallet information for pipes. Mitsui claimed a 60% reduction in man-hours for 70% of the pipe fabrication jobs by utilization of their MAPS system [10] (a system for both design and automated fabrication). A 50% reduction in man-hours was cited in using this system for preparation of pipe piece drawings and material lists. [3]
- Computer aided structural design and production systems were in use in all yards visited. In these systems in particular, the natural growth of computer development and usage has been from the production department back up through the shipyard organization into design and engineering. These systems in general exceed current AUTOKON capabilities in that part coding, nesting and definition of part of the internal ship's structure have been implemented using interactive techniques, minicomputers, and early data base management methods. [3,7,8,9,11,14,15] In the past (1968 through 1976) IHI developed four separate computer systems for structural design and production. Significant reductions in manhours (12.8 manhours/NC tape to 3.5 manhours/NC tape) were reported by Mitsui in utilizing an interactive minicomputer based system for part coding and nesting when compared to their conventional APT like system. [9]
- The use of standards and modules was described in section 5.5. It is apparent that the use of standards with an appropriate computer system has strategic importance in increasing productivity. The following is a quote from reference 5.
 

"Standards and modules show their greatest advantage when integrated with a comprehensive computer system. As the design and production process is consistently modularized, the computer can automatically output necessary drawings, material lists, N.C. tapes, purchasing and production control parameters, etc., from very limited input data. Modifications to meet owner's options are easily available by replacing the input data of applicable modules."

- IHI has implemented an advanced interactive computer aided design system (for both structure and outfitting) called SEABIRD [7,8,11] which utilizes an early data base management system (IMS). This system was used on ten. ships and resulted in a 30% savings in design cost and time. This system is no longer in use due to an excess of experienced designers (in the current depressed market) and the costs required to update it to new computer technology (hardware primarily). IHI states they will use SEABIRD in the future when business improves. A significant aspect of this system is that it makes use of IHI's standards and modules.
- IHI applied over 3900 man-days consulting services and the development of very detailed computer system and program specifications for Italcantieri in the following areas:
  - (1) Hull erection system and scheduling
  - (2) Material control system
  - (3) Budget and cost control
  - (4) Unit outfitting methods and outfitting scheduling system.
  - (5) Automated pipe manufacturing and system
  - (6) Subassembly methods for hull construction.

As a result, over a 6 year period Italcantieri, Monfalcone prognssed from three 260,000 Dwt tankers per year to five per year.

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on observations made in the six Japanese shipyards visited, the following items are cited as the primary reasons for their high productivity:

- (1) The utilization and application of the logic and principals of zone planning and construction.
- (2) The development and use of an very effective material classification scheme for definition, procurement, and control of material.
- (3) The extensive use and continual development of high quality shipbuilding standards and modules.
- (4) The rationalized development and use of effective cost/manhour reducing computer aids.

While these techniques and methods are of unquestioned value in achieving productivity improvements, it is also important to note the human aspects of their application. Japanese shipbuilding personnel are highly educated, trained, motivated and experienced managers and workers, and, therefore exhibit a very high level of individual productivity.

### 6.1 Recommended Projects

A considerable amount of research and documentation of Japanese methods and techniques has already been performed within the National Shipbuilders Research Program and is available with the publication of Outfit Planning[2].

Several key U.S. shipyards (Avondale, Levingston, National Steel, and Sun Shipbuilding) have already initiated studies of IHI's or other leading shipbuilders methods.

Emphasis is being placed within the various panels of the Ship Production committee to identify projects which will assist U.S. shipyards to adopt the techniques of zone planning and construction.

With these considerations in mind, and based upon the conclusions cited above, the project team has developed a series

recommended projects. It should be noted that these recommended projects also address the nine areas cited in the Technology Survey of major U.S. shipyards [1], as those which would require minimum investment to implement. Furthermore, these recommendations are specifically oriented toward projects which will permit a more rapid adoption of the Japanese technology. The following pages detail a series of proposed projects for the National Shipbuilding Research Program.

TITLE : Zone Planning

Background: The book, Outfit Planning, published in December 1979 by the National Shipbuilding Research Program introduced an advanced approach which was developed by Ishikawajima-Harima Heavy Industries CO., Ltd. (IHI). It employs zones very productively, but impacts deleteriously to some degree on shipbuilders' traditional goals to maximize steel throughput by facilitating both outfitting and painting precise zones at specified times. U.S. shipbuilders are adopting this logic and have a need to re-orient traditional hull construction and painting planners. Further, they have a need to teach outfit planners hull construction and painting options.

Objective: Expand the text of Outfit Planning to include hull and painting aspects of zone construction. Specifically, show that the logic for the hull block construction method and for zone outfitting and painting are identical.

Approach: In order to maintain consistency and the same level of comprehension, employ the same resource team, on a level-of-effort basis, that prepared Outfit Planning.

Benefits: Shipbuilders will be able to train all functionaries who impact on planning in a co-ordinated manner.

cost : The overall estimated cost is \$160,000.



**Title:     Zone Planning Example**

Background:   The book Outfit Planning published in December 1979 by the National Shipbuilding Research Program introduced an advanced outfitting approach which was developed by Ishikawajima-Harima Heavy Industries, Inc. U.S. shipbuilders are rapidly acquiring an understanding and are formulating strategic goals. Some have already requested more detailed information to facilitate implementation.

Objective:    Prepare a pamphlet for an IHI ship, which anticipates a type which would most characterize U.S. ship construction for the next decade. It is to contain examples of at least:

- diagrammatics
- a. material ordering zones
- c. block breakdown
- d. rough composite drawing
- e. pallet list
- f. composite drawing
- work instruction drawing
- h. MM, MLP, MLC and MLF
- i. etc.

Approach:    Retain IHI Marine Technology, Inc. on a level-of-effort basis to prepare an English language pamphlet including explanatory material. Also, specify the level-of-effort for one subcontractor to prepare and make modifications needed for publication.

Benefits:    Shipbuilders will be able to implement certain aspects of zone planning pending the end products of other more comprehensive pertinent research projects.

costs:       The estimated overall cost is \$90,000 with one half to be specified for the special graphics and modifications needed for publication. 1 yr.

**TITLE : Zone Planning Educational Aides**

Background: The book, Outfit Planning, published in December 1979 by the NSRP introduced an advanced approach which was developed by IHI. U.S. shipbuilders are already adopting the logic and have expressed a need for educational aides to assist implementation. Planning by zones necessarily means changes in traditional approaches such as those already proven by the world's most competitive shipyards.

Objective: The objective is to use the most effective techniques to describe various aspects of these new methods to lower and middle managers in U.S. shipyards.

Approach: Subdivide and prioritize the entire shipbuilding process into discrete functions. Establish the impact of the new methods on each functional category. Develop specific aides to permit understanding of the objectives and procedures already implemented by very competitive shipbuilders.

Benefits: Primarily due to the near perfect implementation of the zone approach, some shipbuilders abroad expend only 1/2 the time and cost per ship as compared to even the best U.S. shipyards. A general understanding will most certainly cause implementation throughout the U.S. shipbuilding industry. This would assuredly decrease these significant differentials.

cost : The most critical training aide required would address functional and detail design. It's estimated cost is \$150,000. Four additional subjects are estimated at a cost of \$75,000 each.

**TITLE :**     Handbook for Production Process Planning & Engineering

**Background:**   The book Outfit Planning, published in December 1979 by the National Shipbuilding Research Program advised U.S. Shipbuilders of the relatively educated middle managers in the most competitive Japanese shipyards and their very effective development of planning and engineering of production processes. It is believed by the most successful Japanese shipbuilders that U.S. shipbuilders are particularly deficient in not organizing and implementing in a similar manner.

**Objective:**    Describe the pertinent logic, principles and methods of two of the most competitive Japanese shipbuilding firms. Apply special emphasis to organizations and the qualifications of incumbents.

**Approach:**    Retain IHI Marine Technology, Inc. and Mitsui Engineering and Shipbuilding Co. on level-of-effort basis to prepare English language manuals that are well illustrated. Also: specify the level-of-effort for one subcontractor to integrate the materials, develop special graphics and make modifications as needed to produce a single manual.

**Benefits:**    The benefits are optimized and continuously updated rationalized fabrication and assembly processes. These, when recorded as production process standards, are the bases for a shipyard's standard designs and/or provide beforehand necessary guidance for basic, functional and detail design. Further, they are an essential means for a shipyard to retain the accumulation of useful fabrication and assembly experiences.

**Costs :**    The estimated overall cost is \$280,000 with \$100,000 applied to each shipbuilding firm's level-of-effort and the remainder for preparations needed for publication.    2 years.

**TITLE :    Electric Cable Palletizing**

Background:    A few U.S. shipbuilders precut some cable to specified lengths before installation even in the first ship of a class. However, the technique is not fully exploited whereas it is a significant cost saving material control measure in general use in the Japanese shipbuilding industry. Paradoxically, because the USCG and ABS allow electric cable splices specifically to facilitate the shipbuilding process, U.S. shipbuilders have opportunity to obtain greater such benefits than are available to shipbuilders abroad.

Objective:    Describe the pertinent logic, principles and methods of two Japanese shipbuilding firms known to routinely precut cable for palletizing.

Approach:    Retain Mitsui Engineering and Shipbuilding Co., and IHI Marine Technology, Inc. on level-of-effort basis to prepare English language pamphlets including explanatory materials. Also, specify the sub-level-of-effort for one subcontractor to integrate the materials, develop special graphics and make modifications as needed to produce a single pamphlet.

Benefits:    The technique results in lower costs both for material procurement and handling and in vastly improved material controls and adherence to schedules.

cost:    The estimated overall cost is \$140,000 with \$50,000 applied to each shipbuilding firms' level-of-effort and the remainder for preparations needed for publication.    1 year.

**TITLE : U.S. Shipbuilding Standards Program - Long Term Objectives**

**Background:** Japanese shipbuilders have been able to achieve significant reductions in design cost and schedule duration relative to U.S. practice. A significant part of this reduction is due to their extensive design experience and the documentation of this experience in the form of standards. In that the U.S. industry not developed this high level of design experience; and that at this time it is facing the requirement for achieving shorter design and construction periods; an expanded U.S. Shipbuilding Standards Program in the areas of functional design, detail design, and production processes is recommended. It is felt that standards developed in these areas on an industry wide basis would have greater value and acceptance than if developed only within the individual shipyards. Additionally, these standards will be a necessary input to the efficient use of advanced CAD systems that are projected to be available by the mid 1980's.

**Objective:** The development of a comprehensive set of U.S. Shipbuilding Standards in the area of functional design, detail design and production processes. These standards would be developed for the areas of hull structure, machinery, deck outfit, accommodations and electrical for the range of ship types and power plants projected for use in the 1980's and early 1990's. These standards would be used to update the Marad shipbuilding specifications, and would be structured in a manner to facilitate their use in any advanced CAD system. purchased or developed by the industry.

**Approach:** Purchase consulting assistance in the areas of standard development, organization, maintenance and possible purchase of existing standards from a leading Japanese shipbuilding firm (such as IHI or Mitsui) having extensive experience in these areas. Document and distribute the approach used for standards development and maintenance and insure the use of a standard coding system to the extent practicable. Additionally, assistance would be obtained from U.S. shipyards, design agents, owners, equipment vendors and regulatory bodies. Standard development would initially be based upon the Marad standard designs; however, the development of future standards development is envisioned to include the development and maintenance of standards covering the required range of ship types and power plants. The intent would be to maintain the maximum degree of similarity on standardization possible, while retaining the flexibility of individual shipyards or designers being able to easily modify the standards to suit individual service requirements.

**Benefits:** The proposed project would lead to increased U.S. design experience in many areas and the documentation of this experience in-a form usable by shipyards, design agents, shipowners and Marad. This would lead to a significant reduction in design cost and schedule duration, which is a key requirement to the implementation of advanced outfitting techniques such as zone outfitting and to achieving the significant savings in production cost imminent in these approaches. Additionally, documentation of design experience including feedback from all areas will assist in improving the quality of U.S. Design work.

- Costs :**
- (a) Initiate the U.S. Standards Program - state objectives  
develop an RFP, review the Japanese standards approach  
1st half 1980.
  - (b) Develop standards for key ship types 1980-1985  
(including Marad standard design)
  - (c) Expand and maintain program continuing

**TITLE** : U.S. Shipbuilding Standards Program - Functional Design Standards/Modules for Machinery Spaces

**Background**: Japanese shipbuilders have been able to achieve significant reduction in design cost and schedule duration relative to U.S. practice. A significant part of this reduction is due to their experience and the documentation of this experience in the form of standards that include the area of functional design in addition to that of material and fittings as presently covered by the U.S. standards program. It should be noted that the ability to speed up the design process is considered the key to the implementation of advanced outfitting techniques such as zone outfitting.

**Objective**: Develop with Japanese assistance in the technical and standards areas, functional design standards/modules for machinery spaces and related systems for the range of ship types and power ranges covered by the three Marad standard designs. These would include reusable machinery space arrangements; system diagrams; definition of outfit units; pipe passage layouts; definition of system and equipment specifications; and to the extent practical, definition of alternate vendor's equipment for the main engines, generators, and key auxiliaries.

**Approach**: Functional design and standards development would be conducted with the assistance of consulting in the technical and standards areas from a Japanese shipbuilding firm (IHI or Mitsui) having extensive experience in these areas. Additionally, assistance would be obtained from the vendors of main propulsion engines and auxiliary equipment. Functional design including arrangements, system diagrams, etc., would be developed for the three Marad standard designs based upon two main engine vendors. The intent would be to maintain the maximum similarity or standardization possible for this range of applications and power requirements, while retaining the flexibility of individual shipyards or designers being able to easily modify the standards to suit individual service requirements.

**Benefits**: The proposed project would lead to increased U.S. design experience in the area of machinery spaces and the documentation of this experience in a form usable by shipyards, design agents, shipowners and Marad. This would in turn lead to a significant reduction in design cost and schedule duration, which is a key requirement to the implementation of advanced outfitting techniques such as zone outfitting and to achieving the significant savings in production cost imminent in these approaches.

**Costs** : To be developed.

**Schedule**: 12 months - mid 1980 to mid 1981 depending upon funding.

**TITLE : Construction Services**

Background: For many years, U.S. shipyards have been plagued by a "Helter-Skelter" approach to supplying construction services to most all work areas of ship construction. Poor construction service practices result in poor housekeeping typified by cluttered decks and access passage ways. These invite poor working conditions with resultant waste of manhours and potentially unsafe working conditions.

Objective: Develop a manual, for distribution to shipyards, that would describe and illustrate various methods by which construction services can be installed to conveniently supply all the needed services to shops and ships in a preplanned manner.

Approach: The developer of the manual should study the various yards in America and selected foreign yards to determine present practices. The problem covers all areas of ship construction and a few candidate areas are as follows:

- 1) Scaffolding is always a problem particularly when needed in such high and hazardous places as the underside of the Upper Deck in large tankers and/or Bulk Cargo Ships. presently the scaffold builder is faced with a heel-hanging operation to both build and remove such scaffolding. A possible solution is to have engineering, during development of structure drawings, design and detail special scaffolding brackets, etc., which could be installed during assembly of a hull block. Hopefully these would be approved by the owner of the vessel to permit welded chocks, etc., to remain on the structure. This would make the scaffold builder's job safer in both installation and removal operations.
- 2) Temporary lighting, compressed air service, water for fire fighting and other uses, gases used for cutting and welding, temporary phone service, etc., for on-board use. All of these services have posed big problems. Normally they are run from the ground and over the side of the vessel at the most convenient place for a worker to use at a given time. Many of these service lines remain in place and tend to accumulate into a mass of cables and hoses, mostly underfoot and down ladder ways. A possible solution for on-board use, is to have a series of portable archways installed on the top-most deck of the vessel with all of the above services suspended from the top of the arch high enough above the deck to permit passage below. Standard length pipe sections (flanged) could be developed and manifolds for each system could be mounted on the archways at convenient spacing. Hoses could be used to connect systems to towers at the side of the ship which would carry service lines from distribution systems on the ground.



- 3) Improved material handling methods for all types of materials and equipment such as pallets: types and sizes, types of vehicles used to handle and transport, methods to lift aboard ship.
- 5) Welding power sources and welding power distribution systems.
- 6) Temporary ventilation systems for confined spaces.
- 7) Rigging methods and equipment to help trades people handle and install all manner of equipment and materials in both shops and ship.
- 8) Access methods to assist men to be transported from ground to work areas on board ships -- both in the interior of the vessel and on the exterior. This item should also include a planned arrangement of temporary openings in ship structure for both horizontal and vertical access for men and construction service lines.

**The** above list is in no way to be considered complete and the developer of the manual should work with shipbuilders to assure that all possible areas of construction service problems are included in this survey.

Schedule: One year and 6 months from contract award.

Benefits: If properly approached and accomplished the benefits would include:

- 1) Improved Safety (dramatically)
- 2) better working conditions will produce:
  - more efficient work environment
  - reduced man hours
  - shorter building schedules

cost : The estimated cost is \$120,000.

References: "Project Safe Yard" L.B. Naval Shipyard  
"Design for Producability", NSRP

**TITLE :** Jigs, fixtures and special tools

**Background:** Observations of fabrication, assembly and installation operations at Japanese Shipyards reveal many jigs and fixtures are employed to assist in the joining of various parts and assemblies. Many of these special tools could be readily adopted by U.S. Shipyards to assist tradesmen in numerous production operations.

**Objective:** Develop a well illustrated manual which describes the use of jigs, fixtures and special tools.

**Approach:** The researcher should canvas shipyards, both foreign and domestic, for any jigs, fixtures or special tools now in use. Review equipment available from specialty-tool manufacturers who may have many such tools already available. (An example is the Ener-Pac Co. who markets a modified Jack clamp using a small portable hydraulic jacking device for aligning structures for joining.)

**Schedule:** Estimated duration is 1½ years after award of contract.

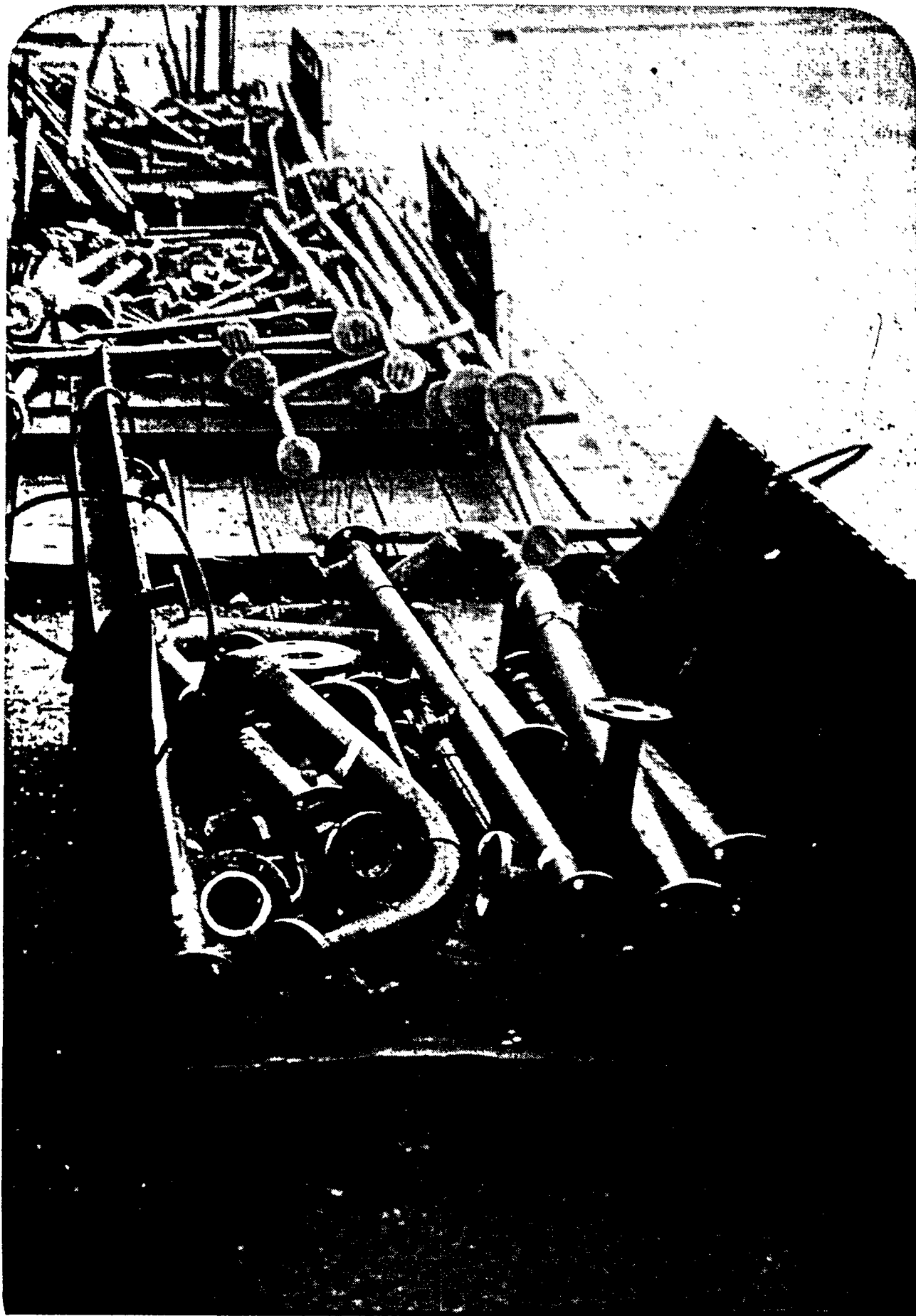
**Benefits:** The use of special jigs, fixtures and tools can yield:

- Safer and better working conditions
- Reduced manhours and cost
- More efficient use of material and services

**cost :** The estimated cost is \$100,000.

## 7..0 GRAPHIC EXAMPLES

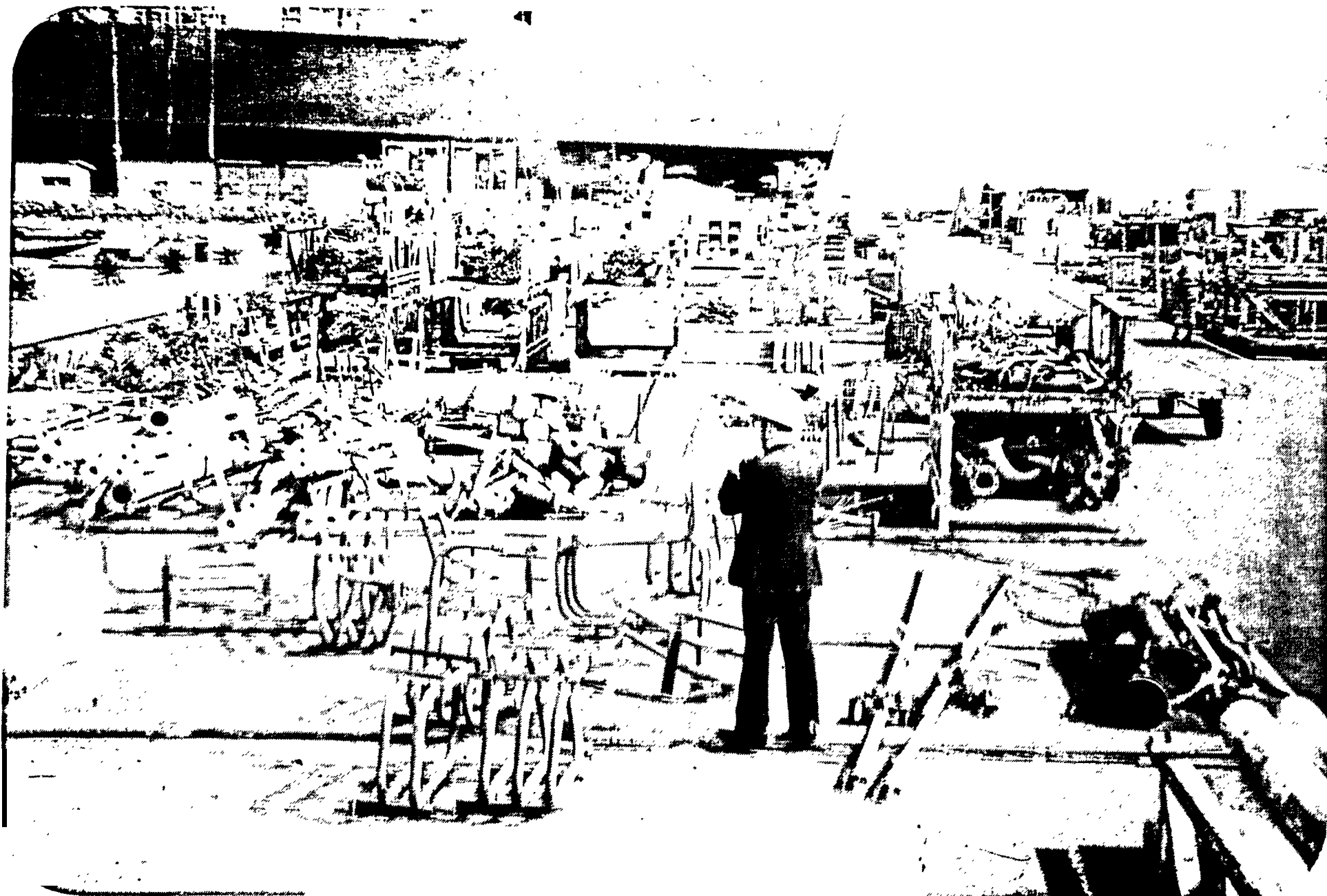
The following pages contain photographic illustrations of various Japanese shipbuilding techniques.



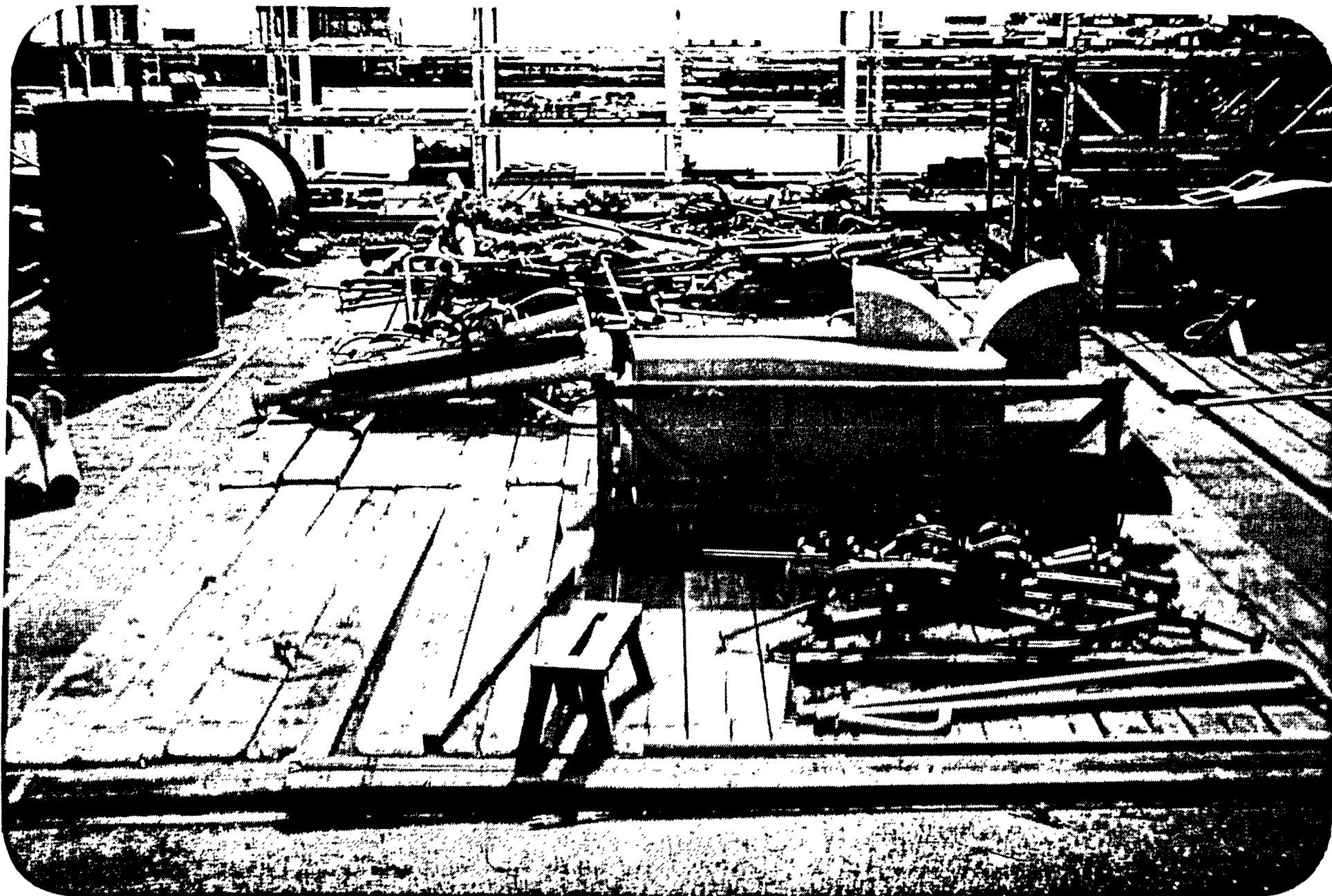
Outfit palletizing utilizes standard containers which may easily be handled by crane or forklift. Mitsui, Chiba.



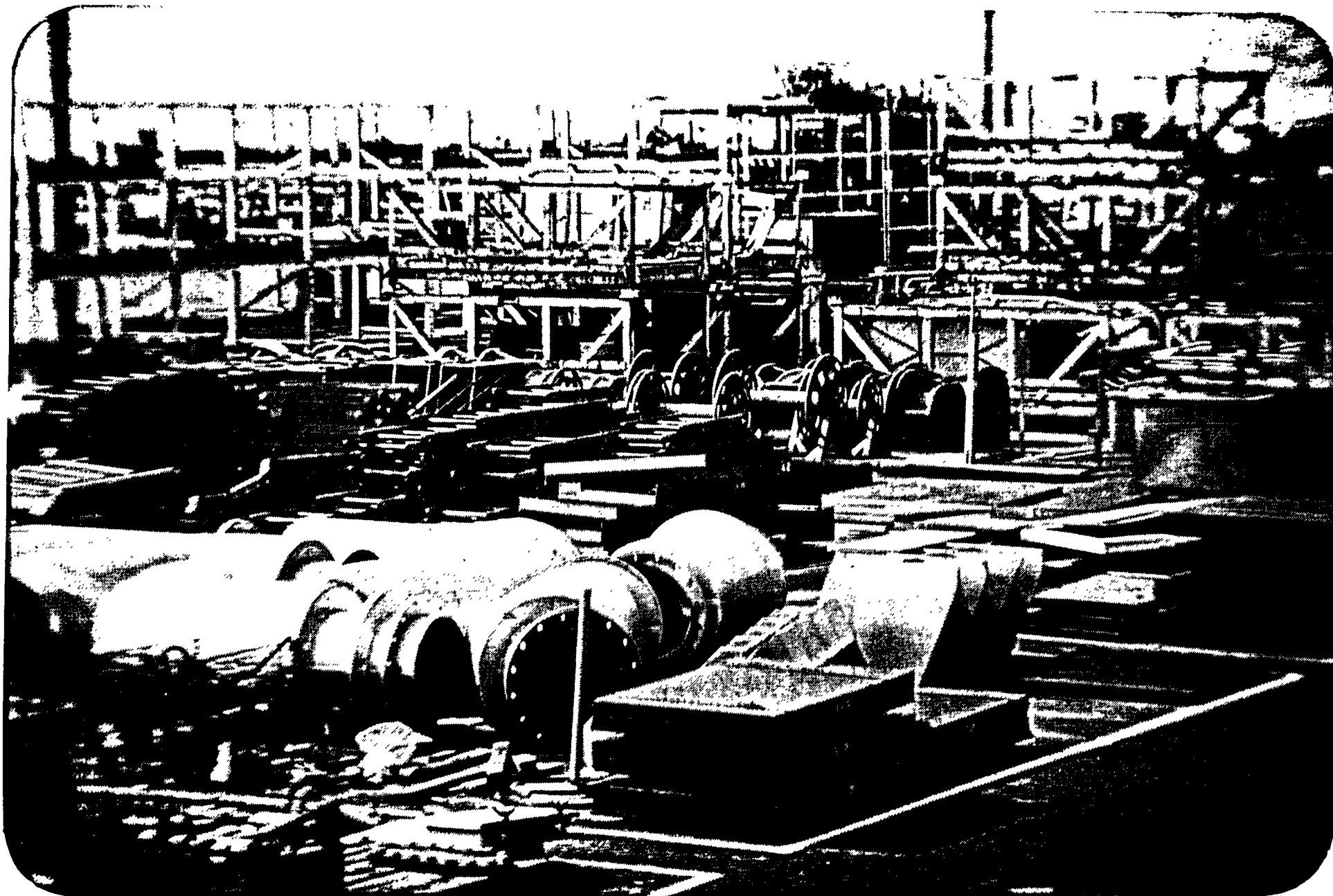
Subcontractor provided pipe supports which have U-bolts temporarily attached for ease of in-process material control. Mitsui, Tomano.



Various views of palletizing area for outfit material. Mitsui, Tomano.



Various views of palletizing area for outfit material. Mitsui, Tomano.



Various views of palletizing area for outfit material. Mitsui, Tomano.

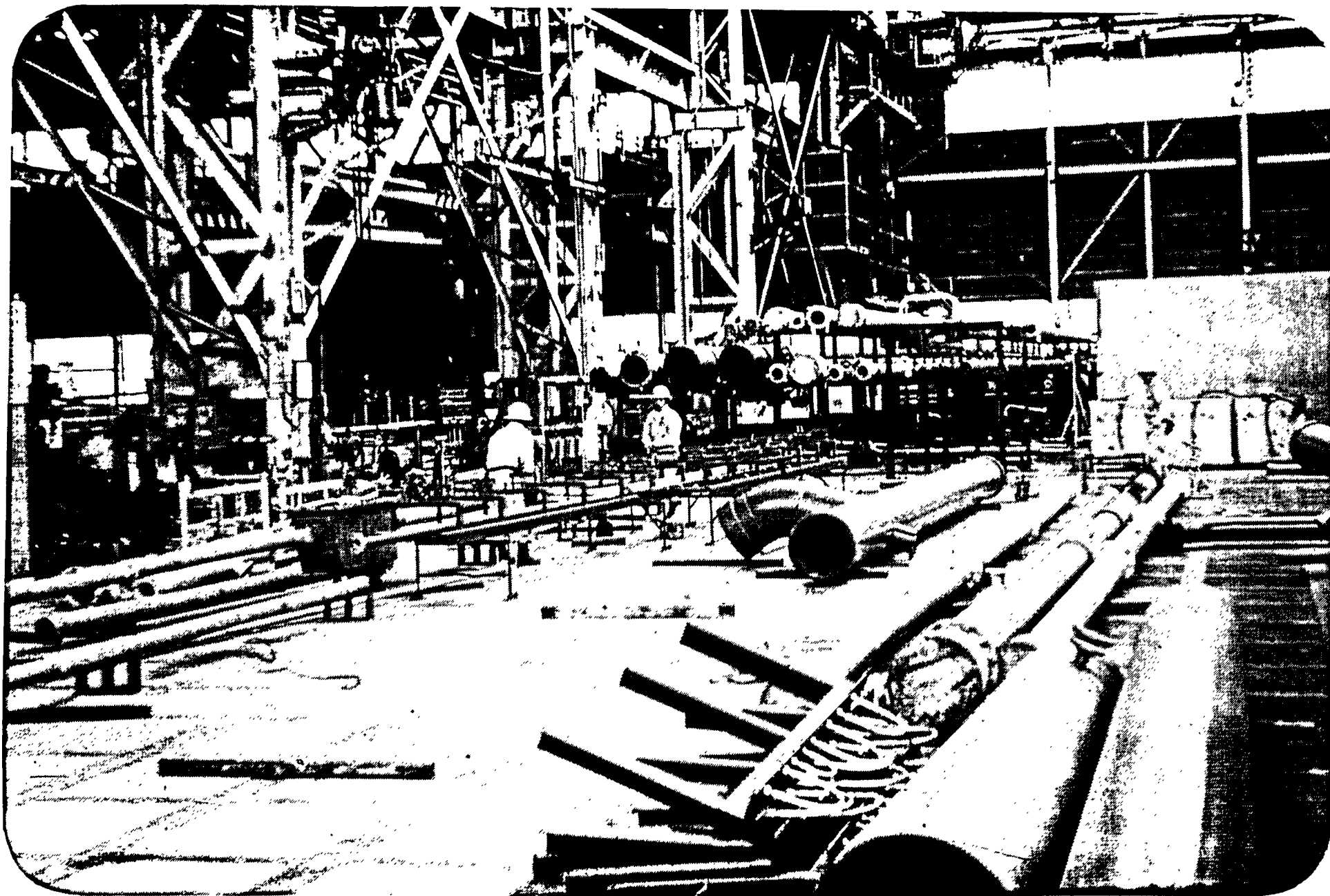




Views of subcontractor provided fabricated materials,  
delivered in lots that match specific pallets. IHI, Kure



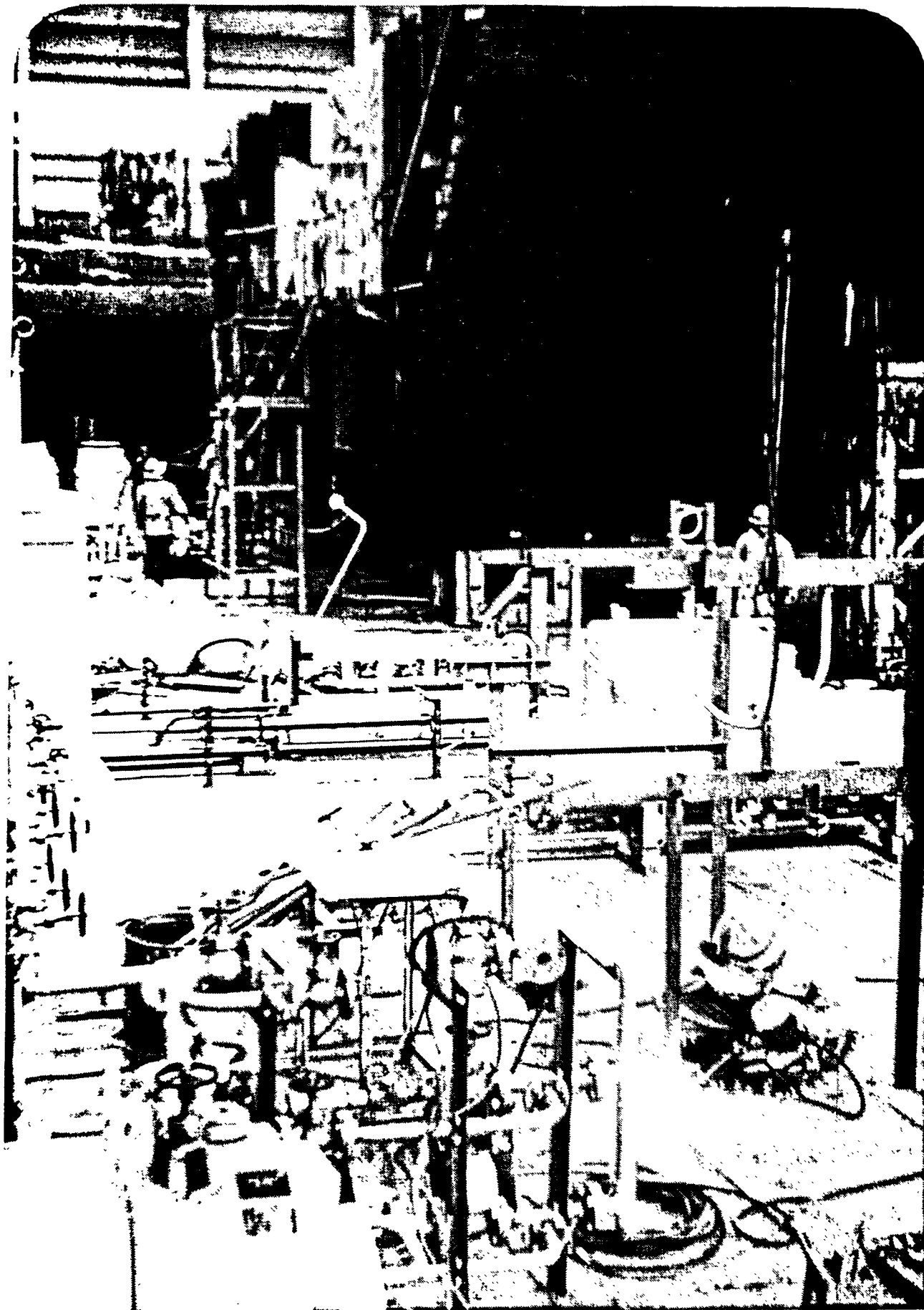
Views of subcontractor provided fabricated materials, delivered  
in lots that match specific pallets. IHI Kure.



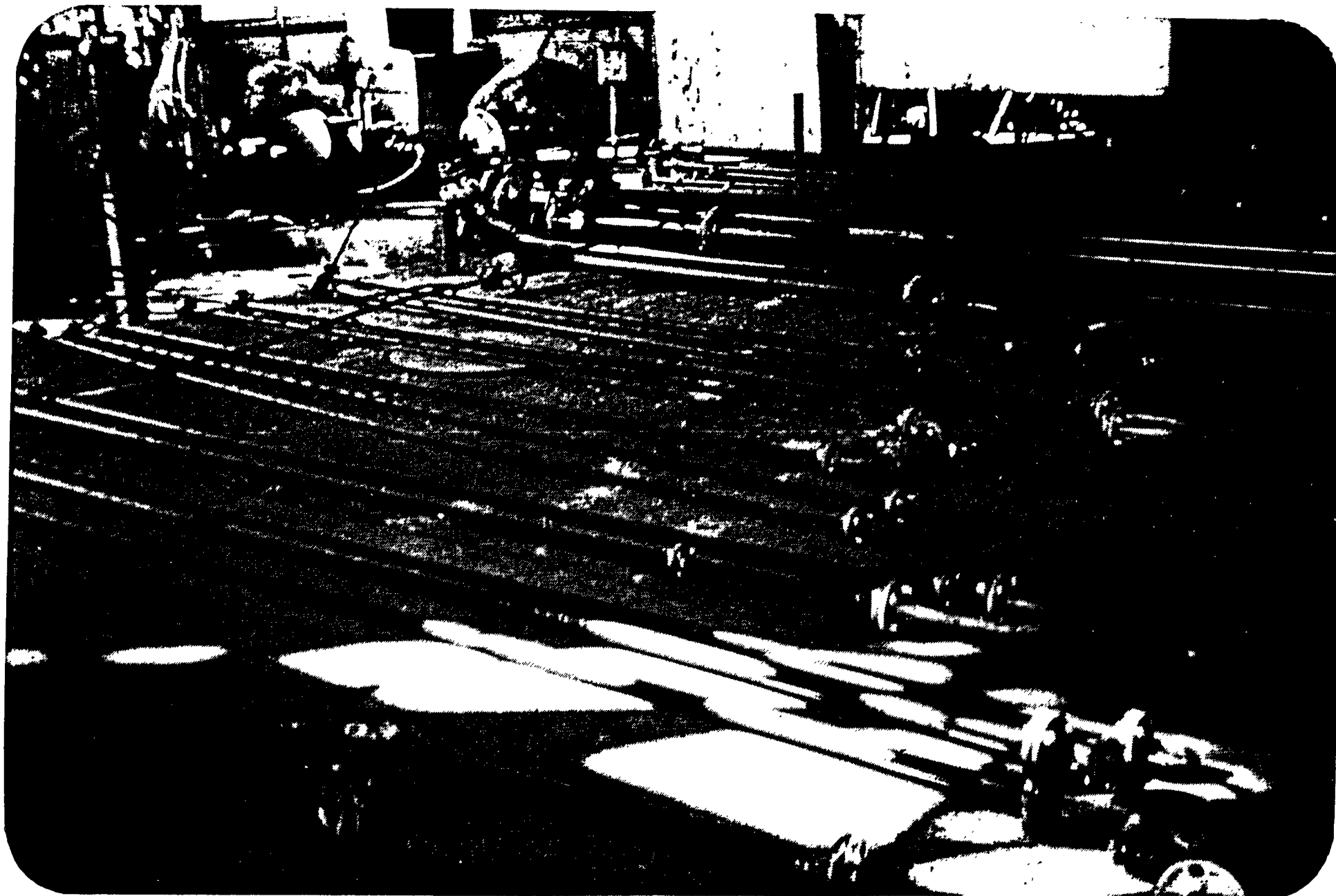
On-unit outfitting in progress. IHI, Kure.



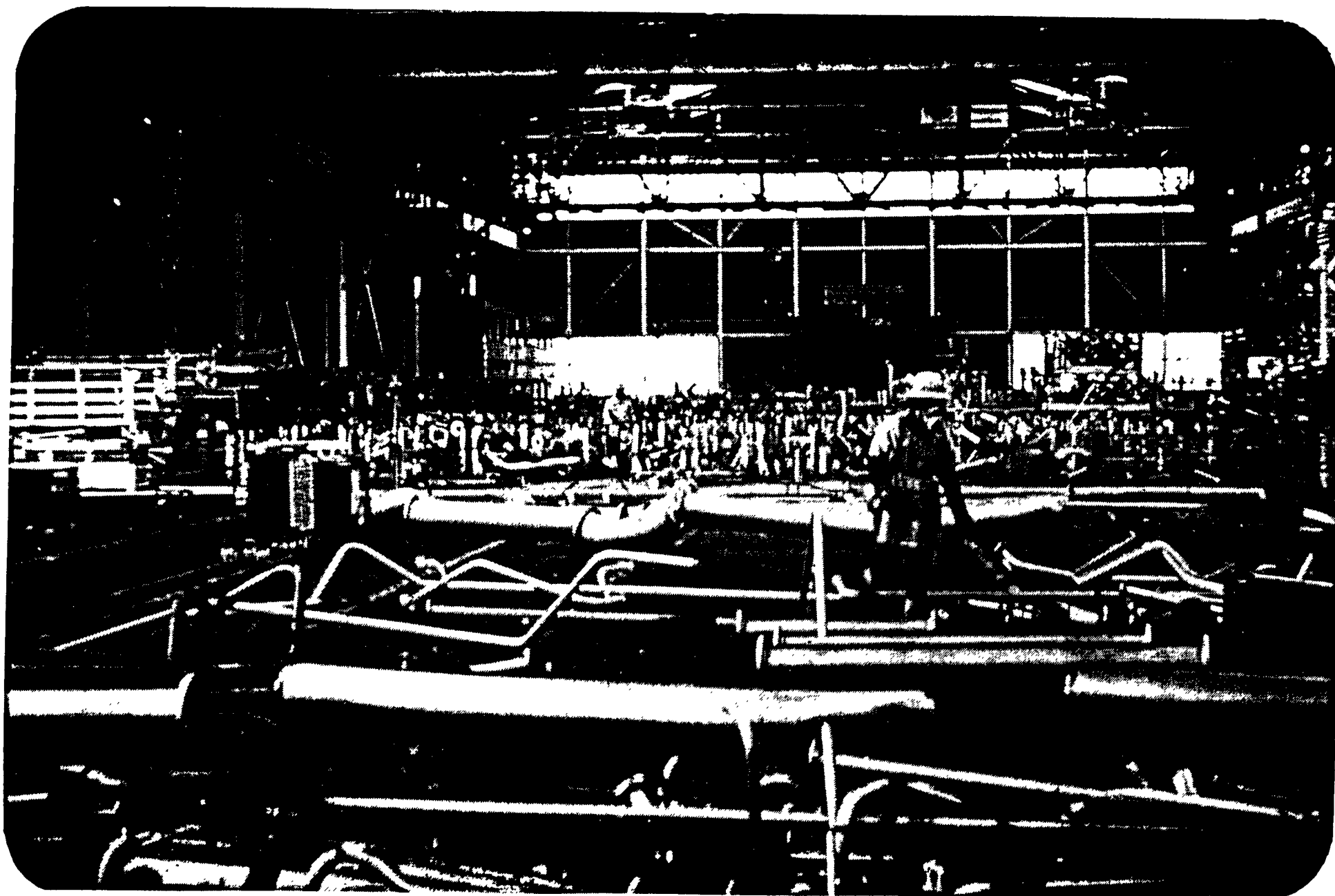
Composite drawing usage at the fabrication stage for  
on-unit outfitting. IHI, Kure.



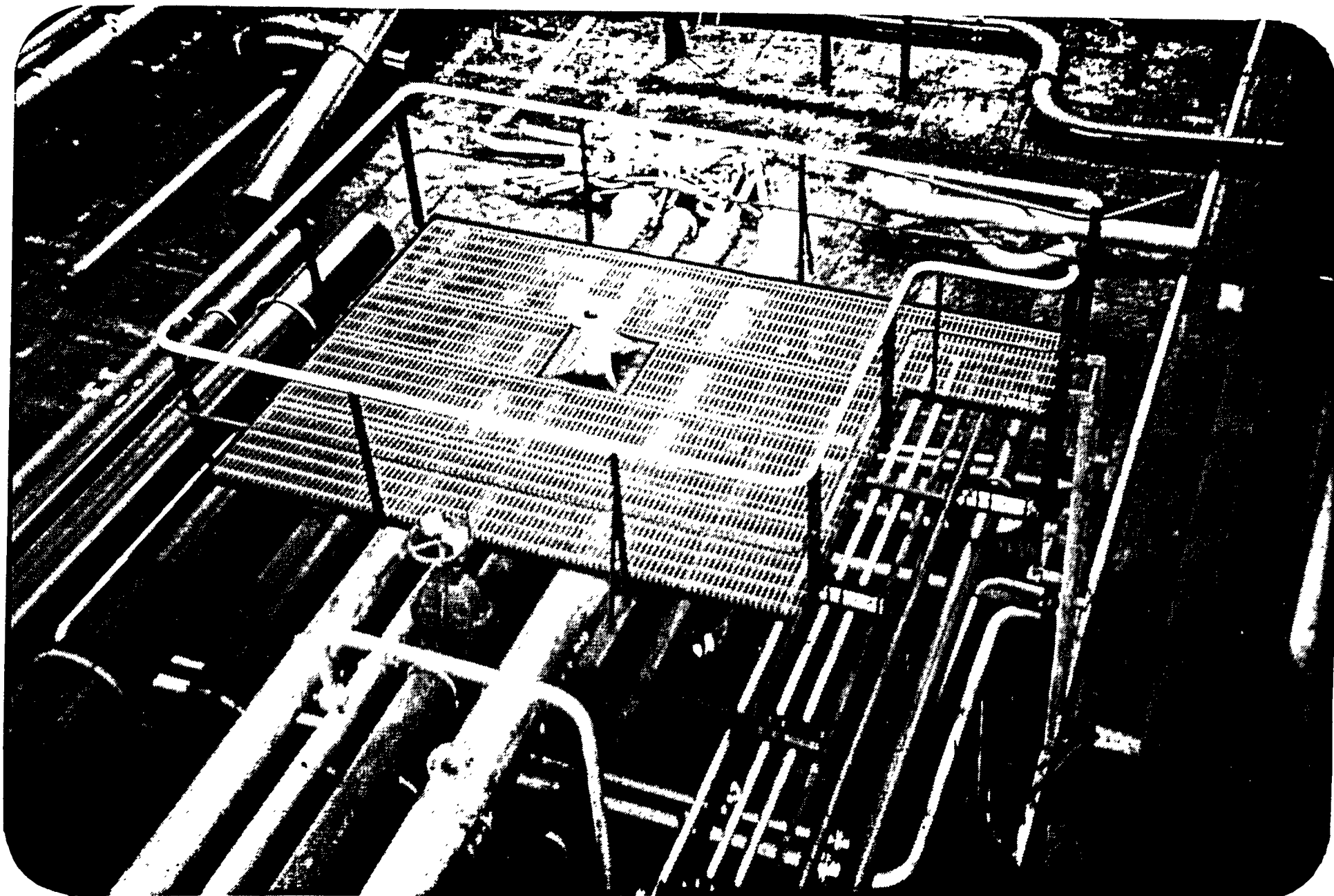
On-Unit and on-block outfitting in progress.  
IHI, Kure



Pipe pieces assembled together for test. NKK, Shimizu.

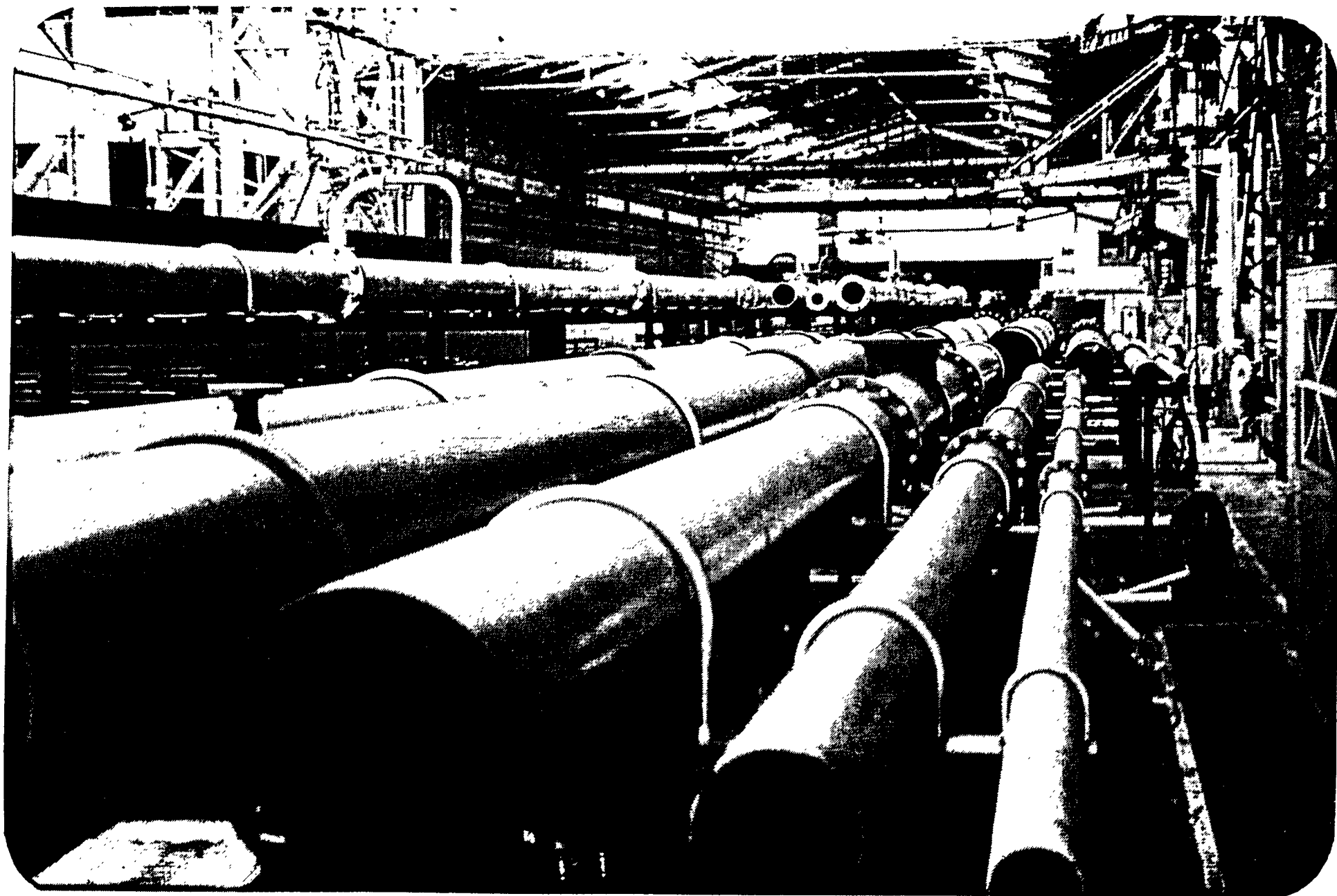


Use of pipe shop area for other than fabrication: 25%  
devoted to sorting by coating system, cleaning and painting;  
25% devoted to palletizing



A unit with walkway and handrails attached. IHI, Kure.

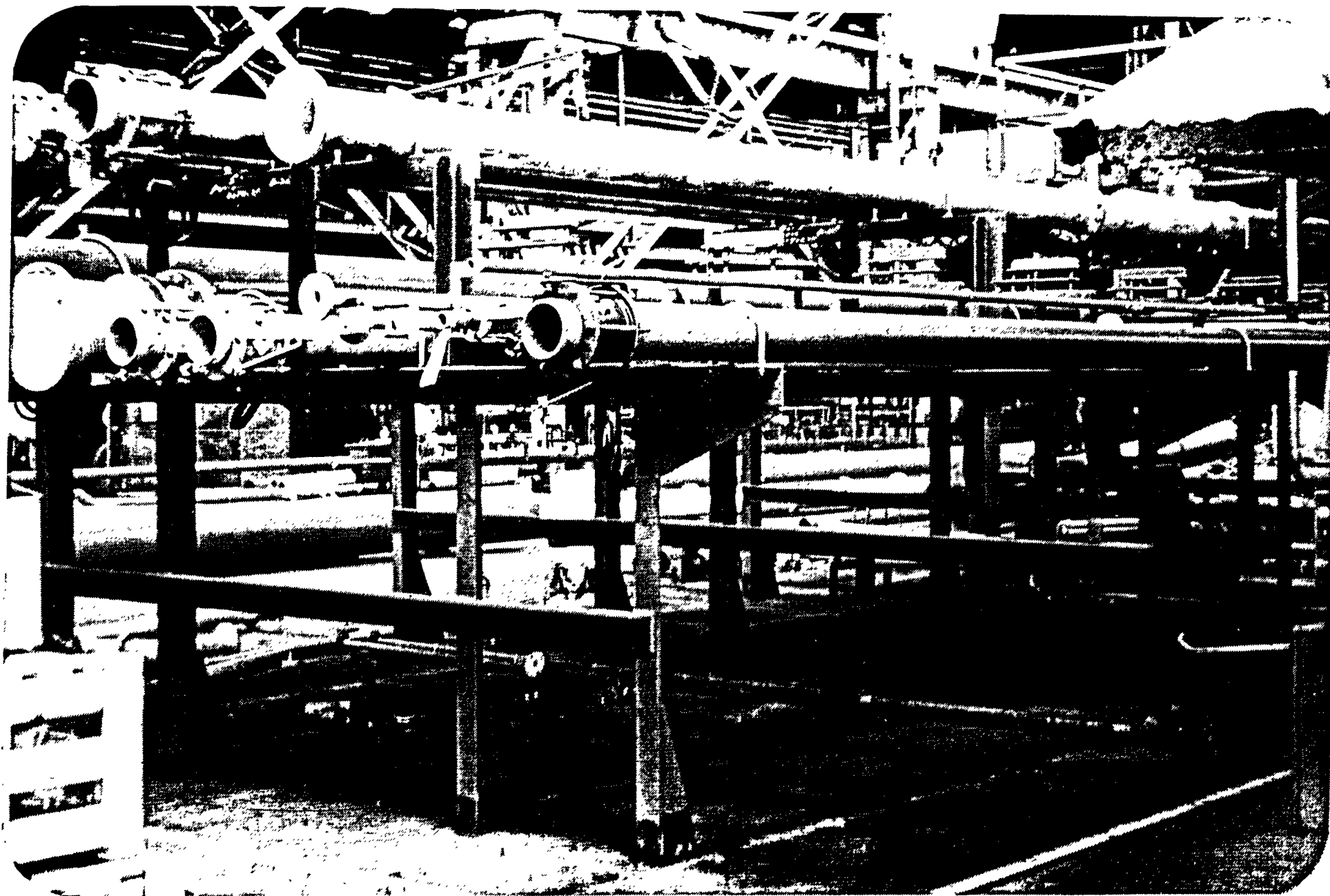




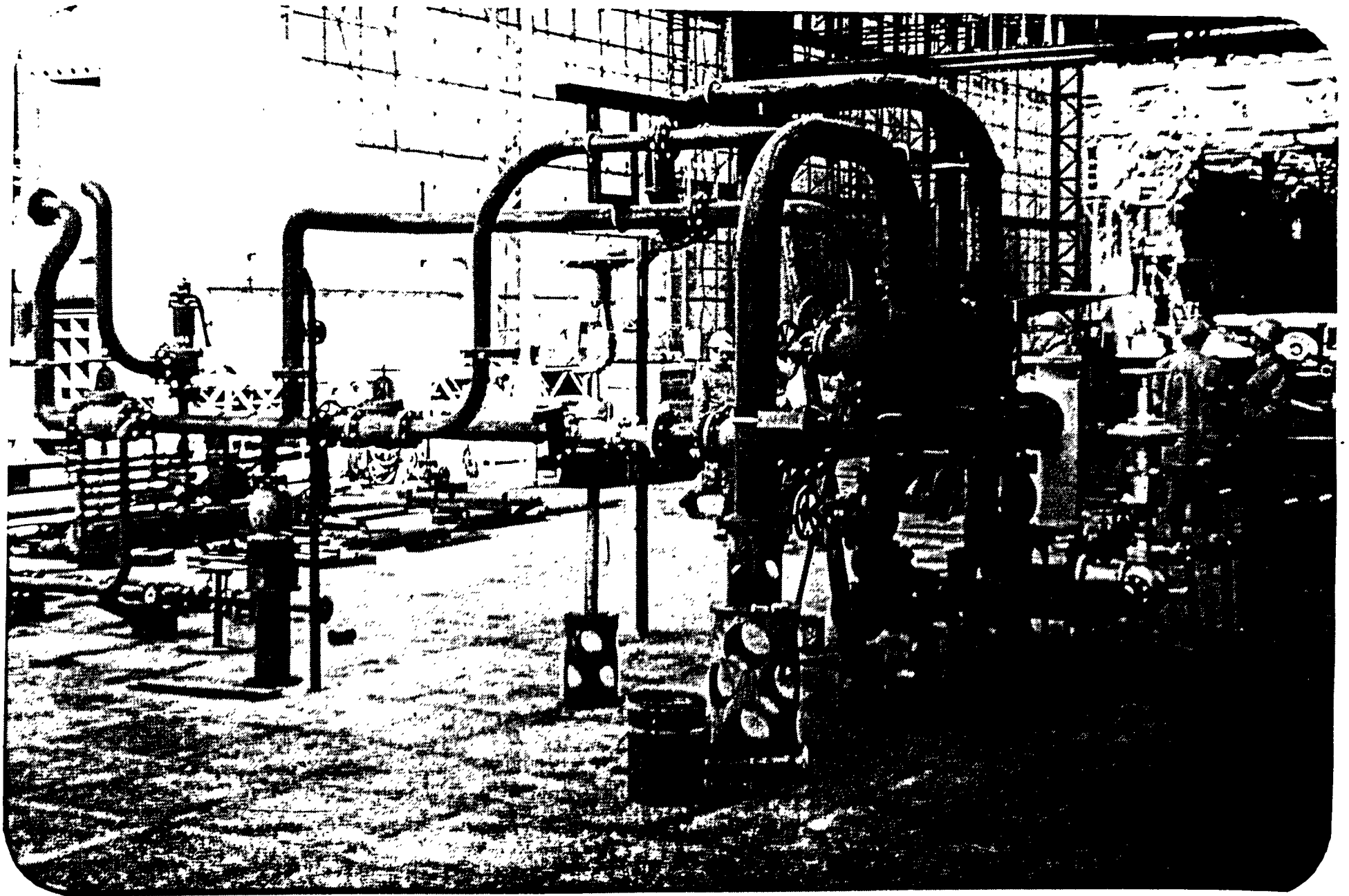
Example of on-unit outfitting. IHI, Kure.



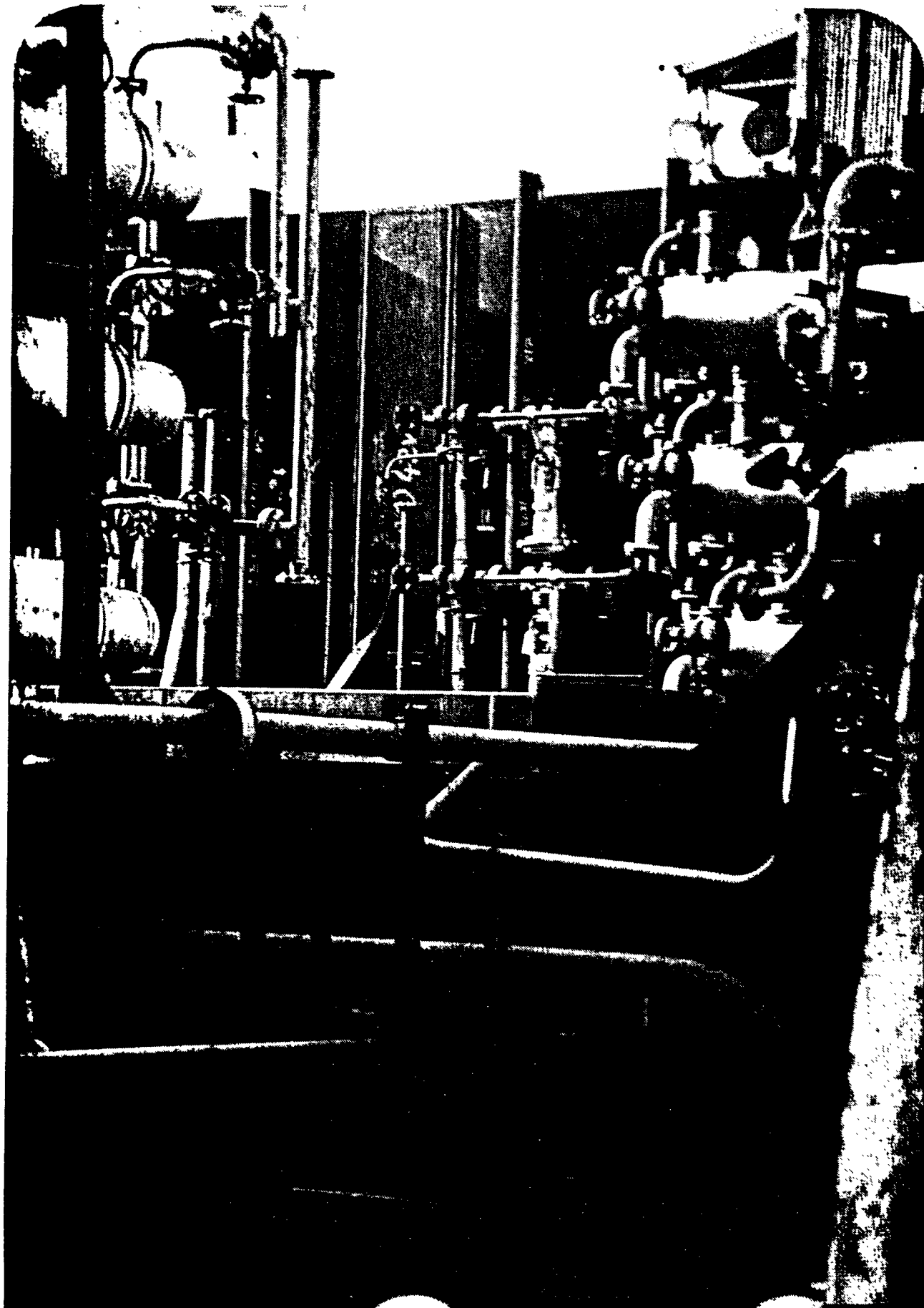
Example of on-unit outfitting. Mitsui, Chiba.



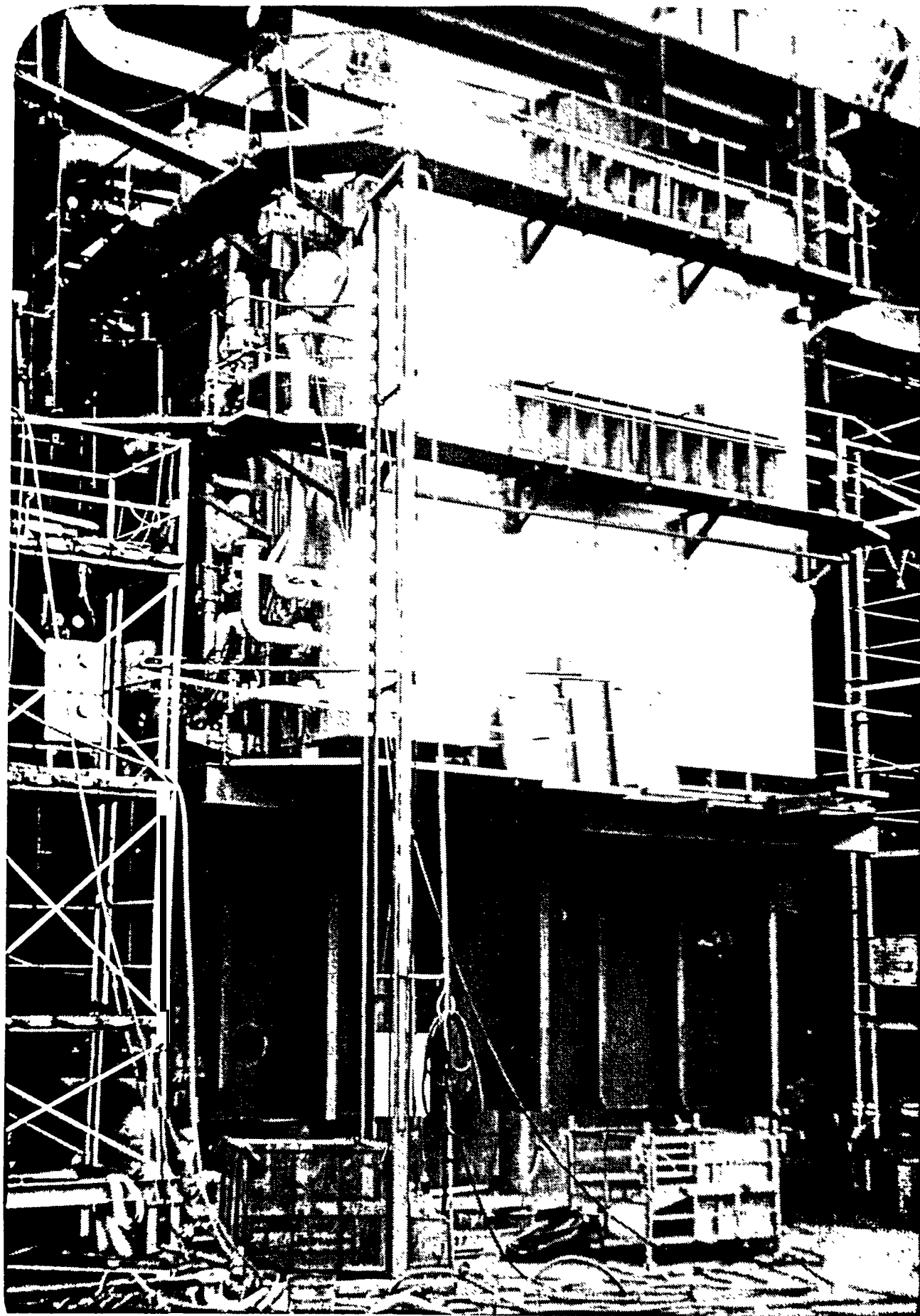
Example of on-unit outfitting. IHI, Kure



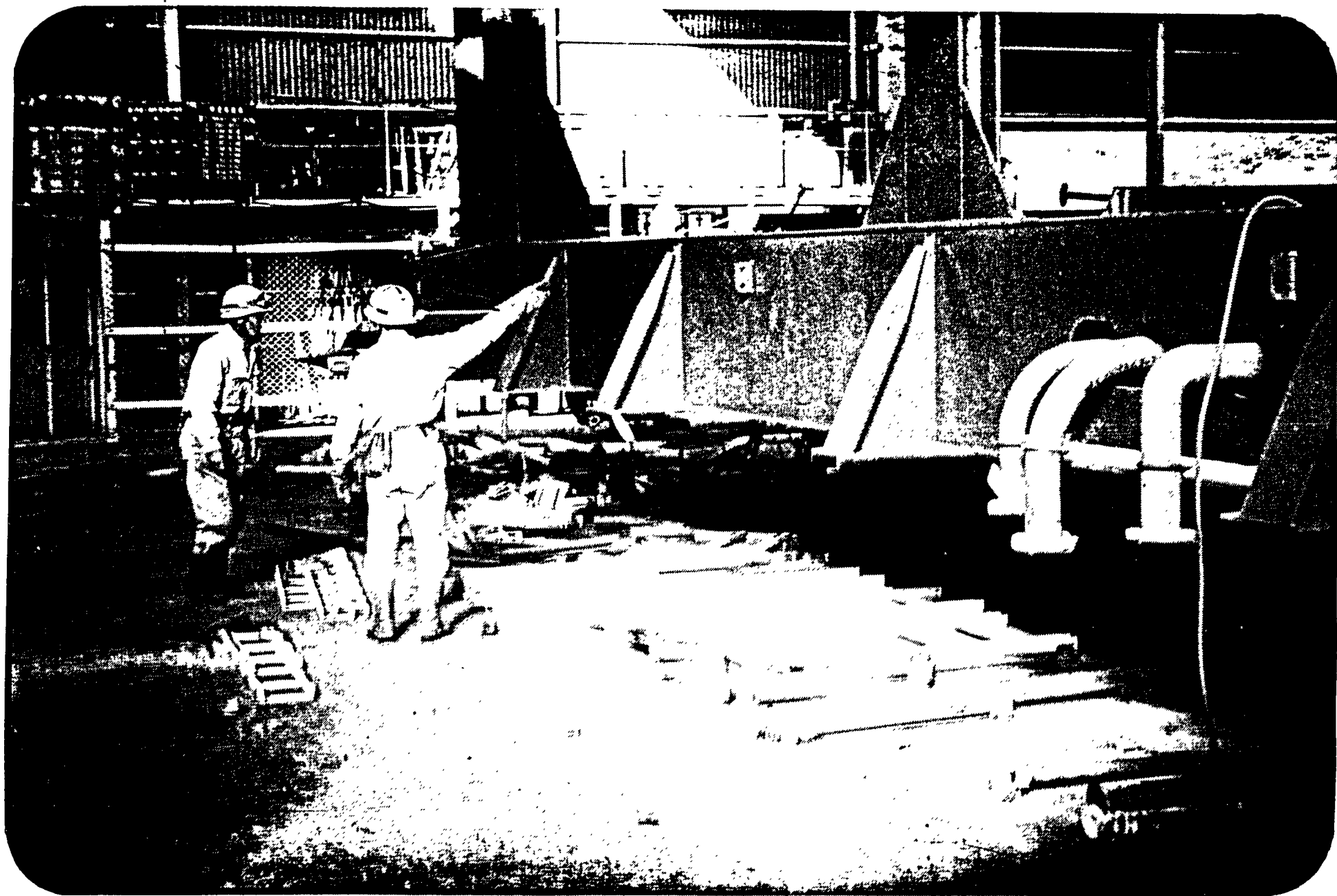
On-unit outfitting illustrating the use of various  
standardized support devices. NKK, Shimizu.



On-block outfitting. Mitsui, Chiba



On-block outfitting. IHI, Kure

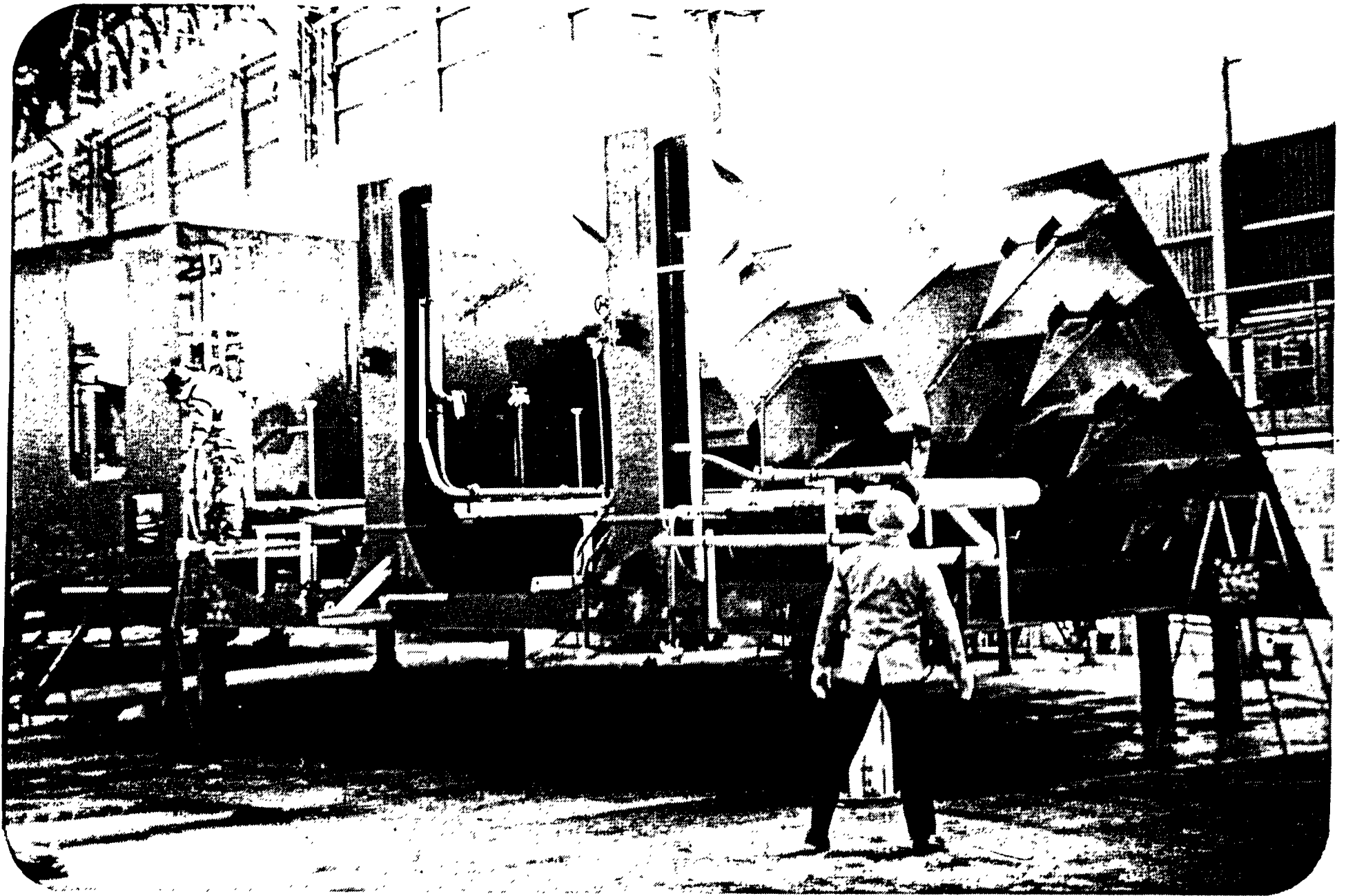


Palletized material at site of on-block  
outfitting. IHI, Aioi.

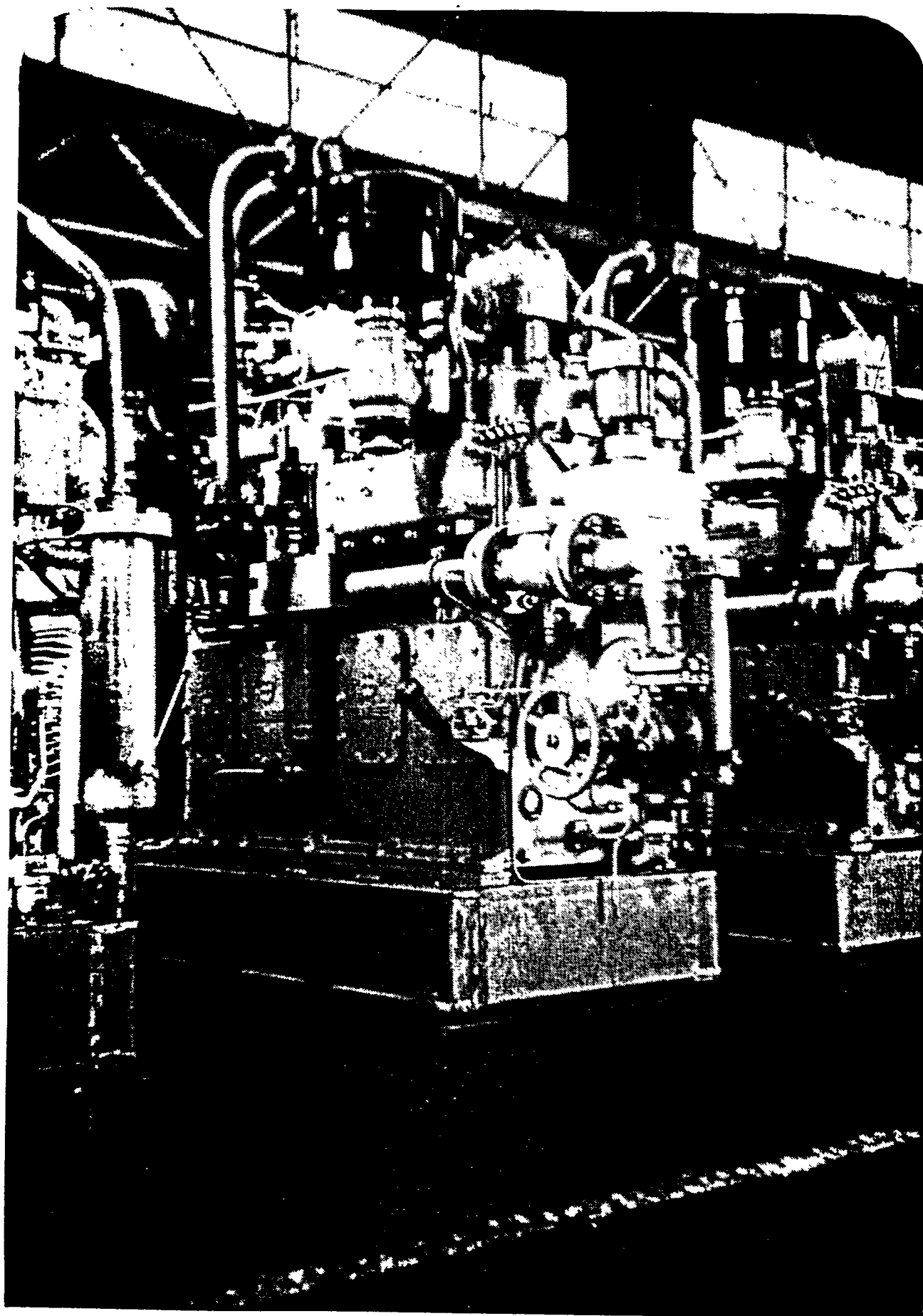


Curved panel structural block outfitted  
upside down. IHI. Aioi..

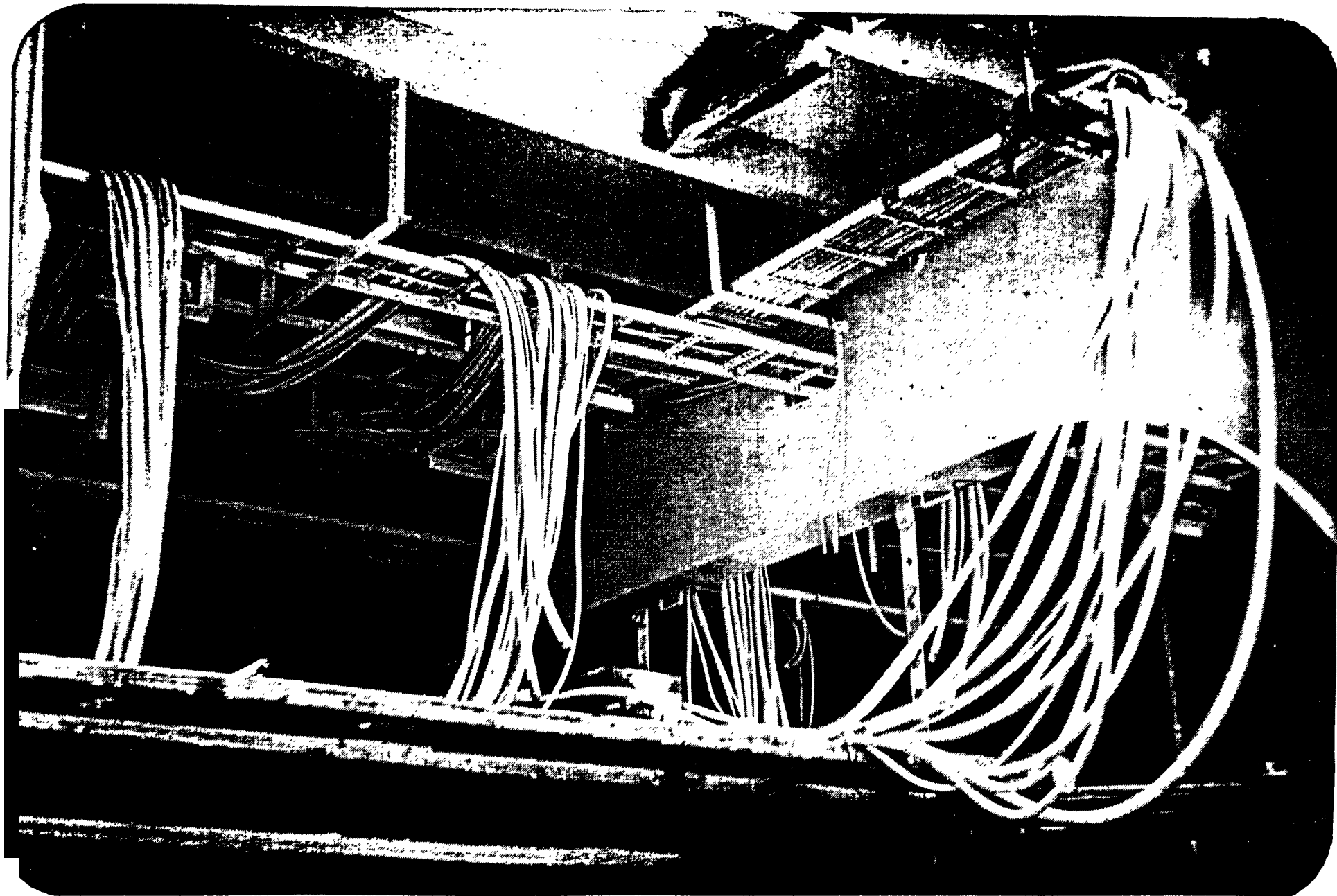




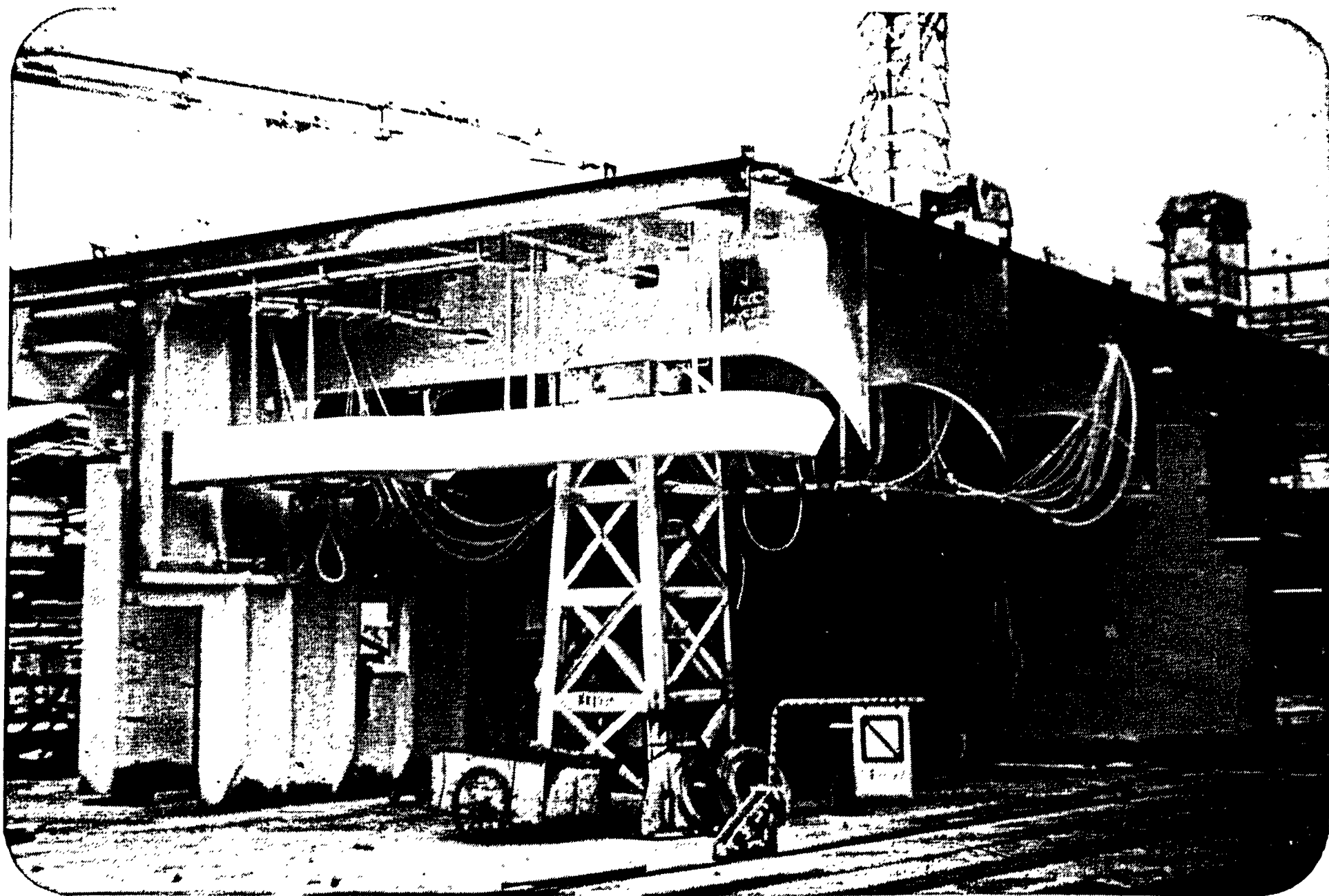
Curved panel structural block outfitted  
upside down. IHI, Aioi.



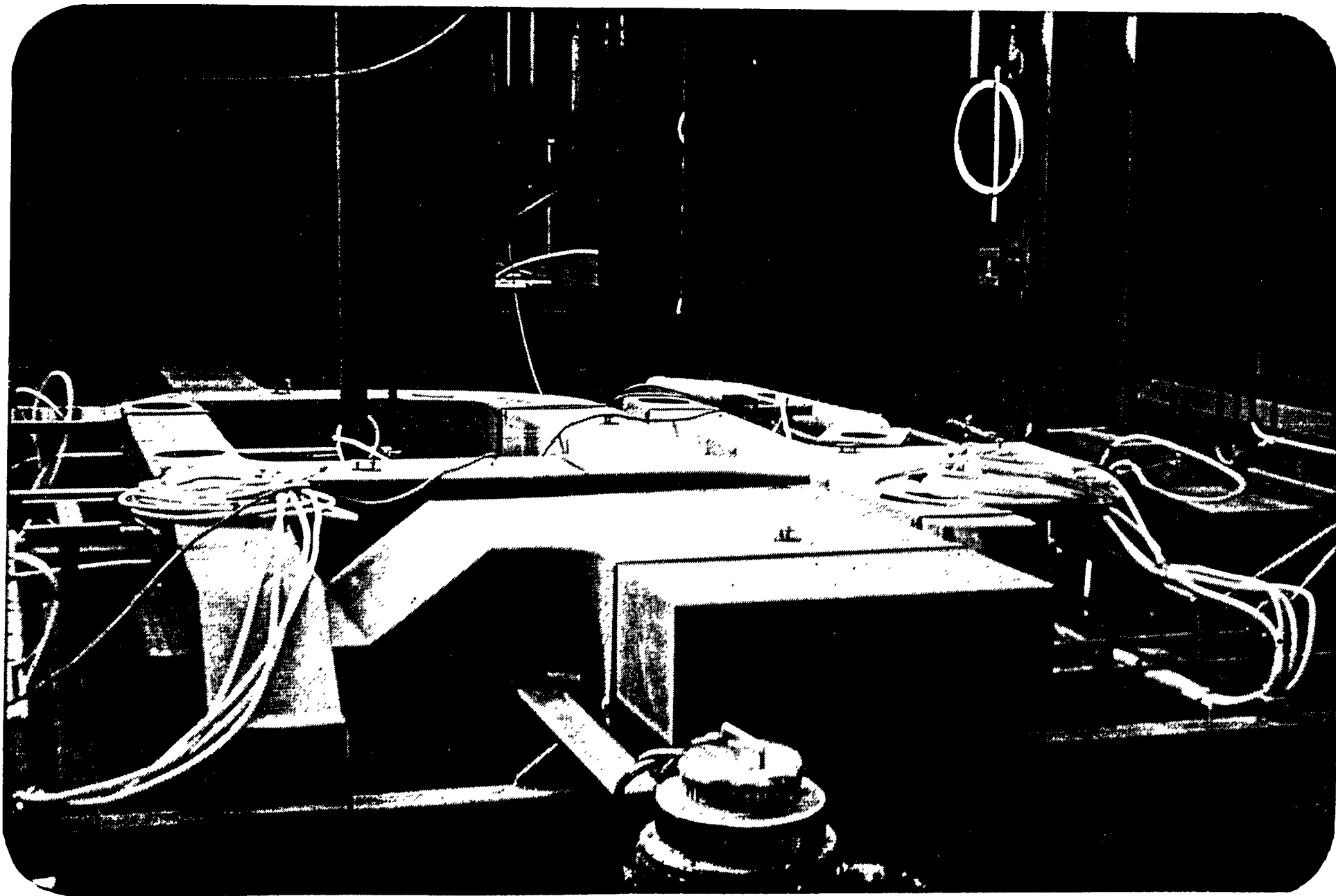
Subcontractor provided diesel generators with foundations and some piping attached. Mitsui, Chiba.



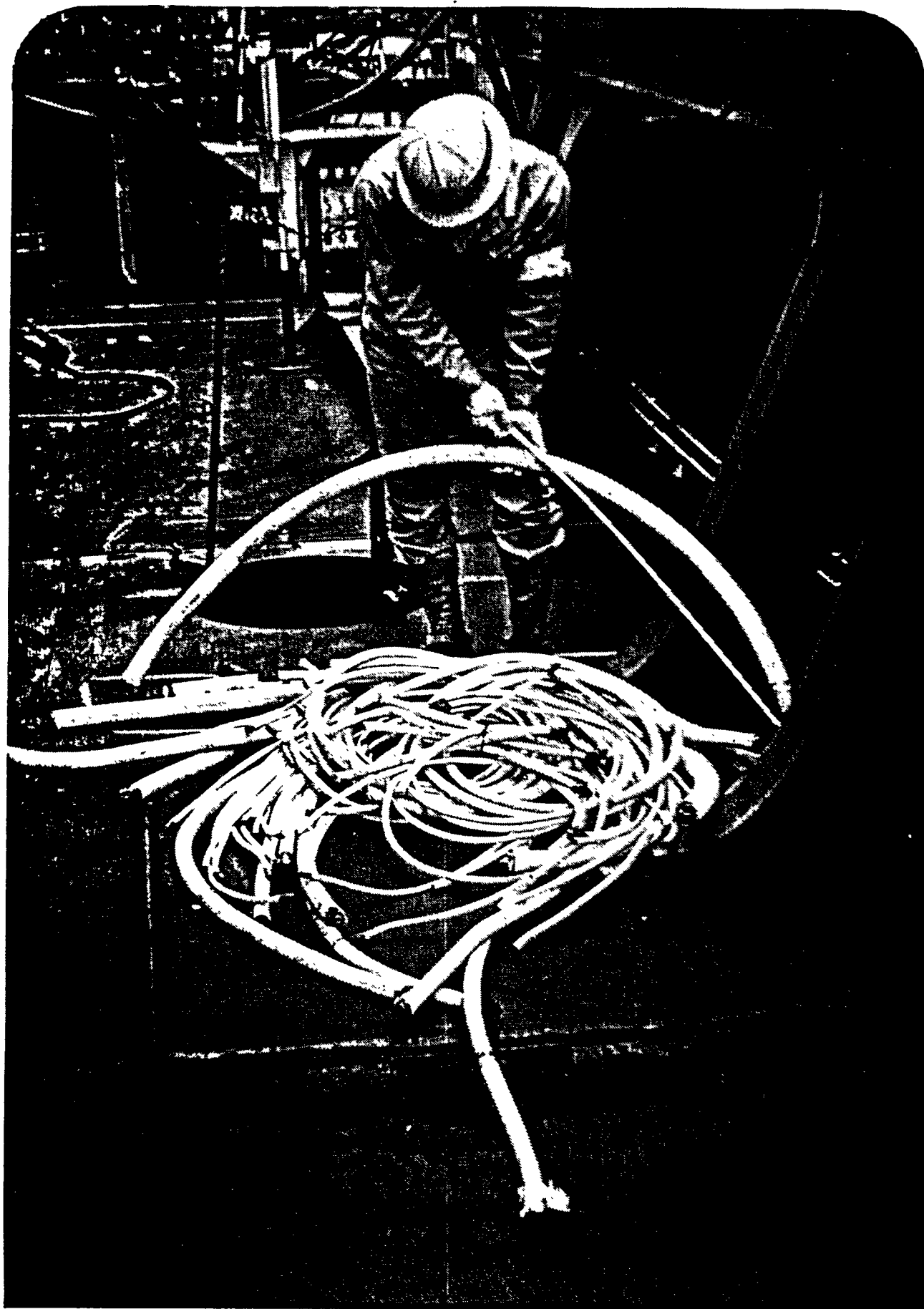
On-block installation of pre-cut (palletized) cable.  
IHI, Kure.



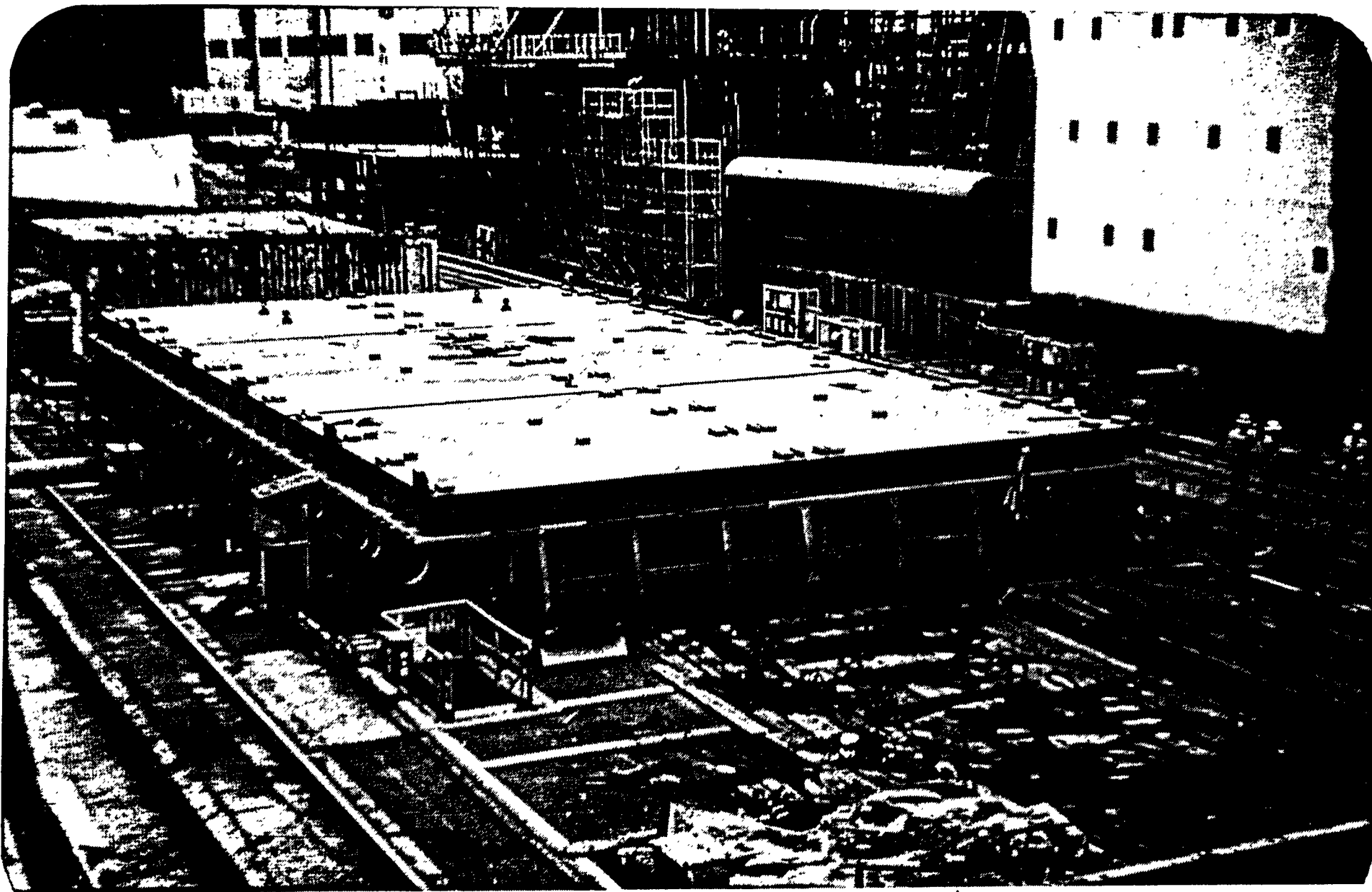
On-block installation of pre-cut (palletized) cable.  
IHI, Kure.



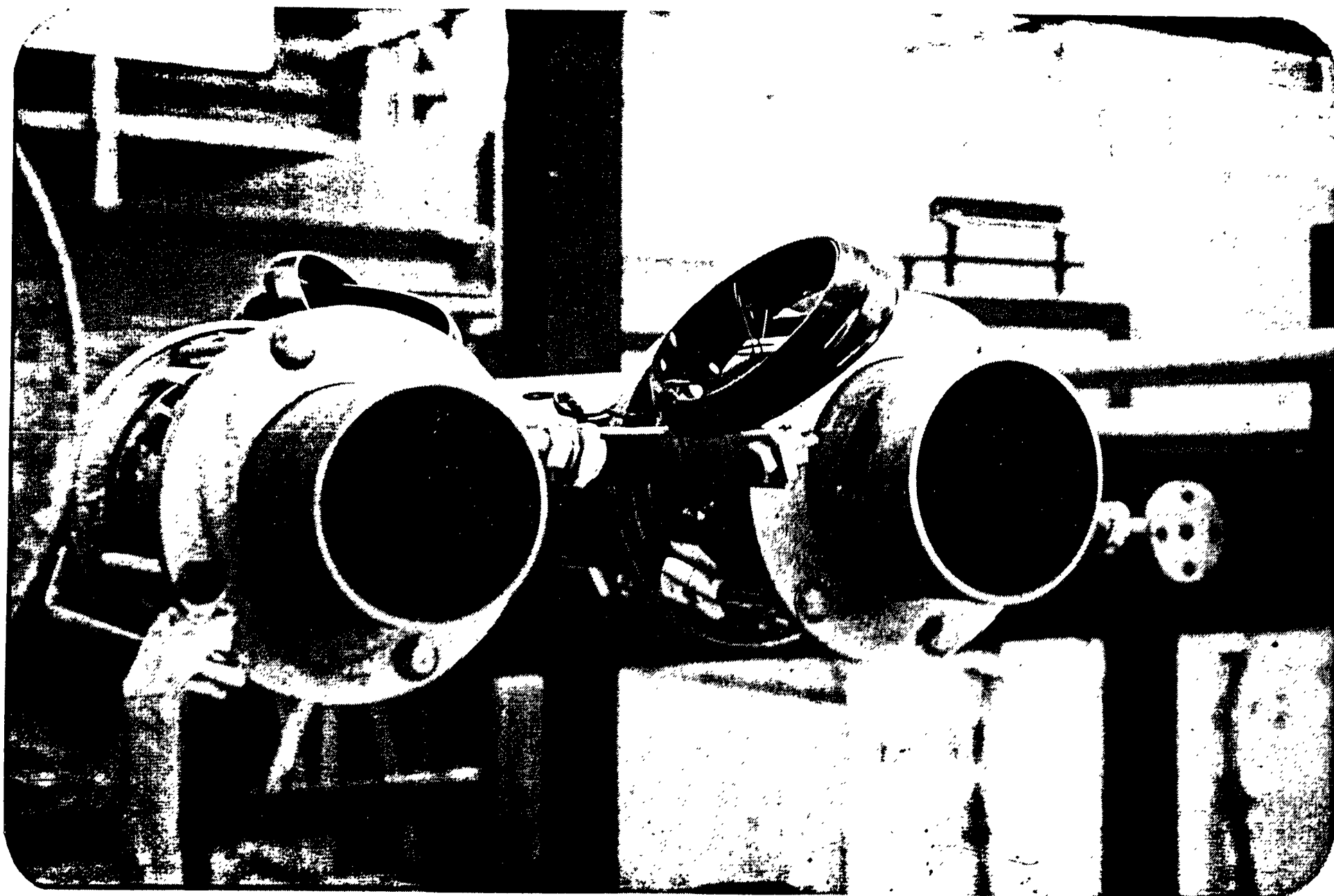
On-block installation of pre-cut (palletized) cable.  
IHI, Kure



Remnants of precut (palletized) electric cable average  
less than 2 meters in length regardless of cable diameter  
IH1, Kure<sub>m</sub>

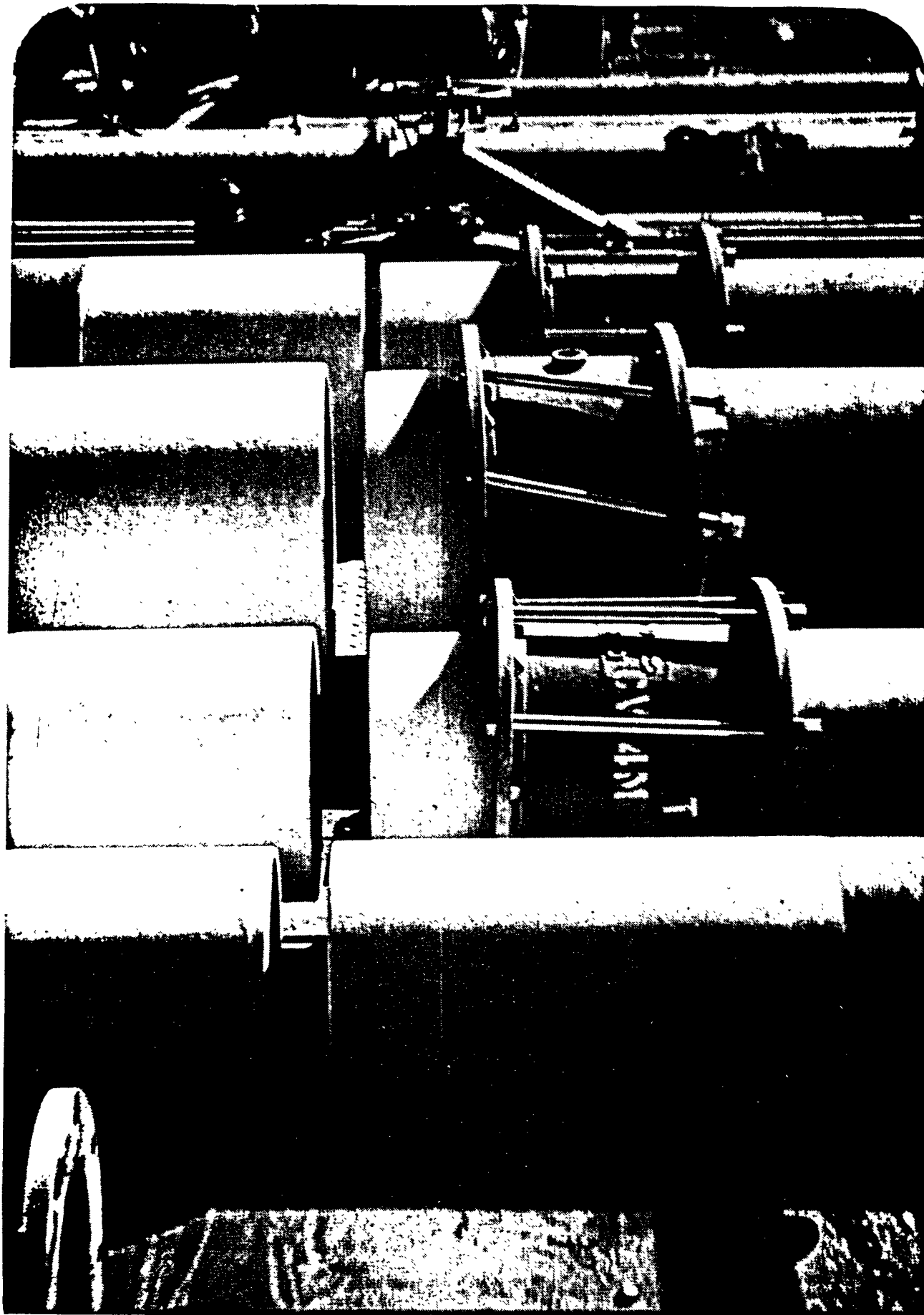


Ground outfitting and assembly of containership hatch coamings with hatch covers, including the completion of all doging, seating and gasketing. IHI, Kure.

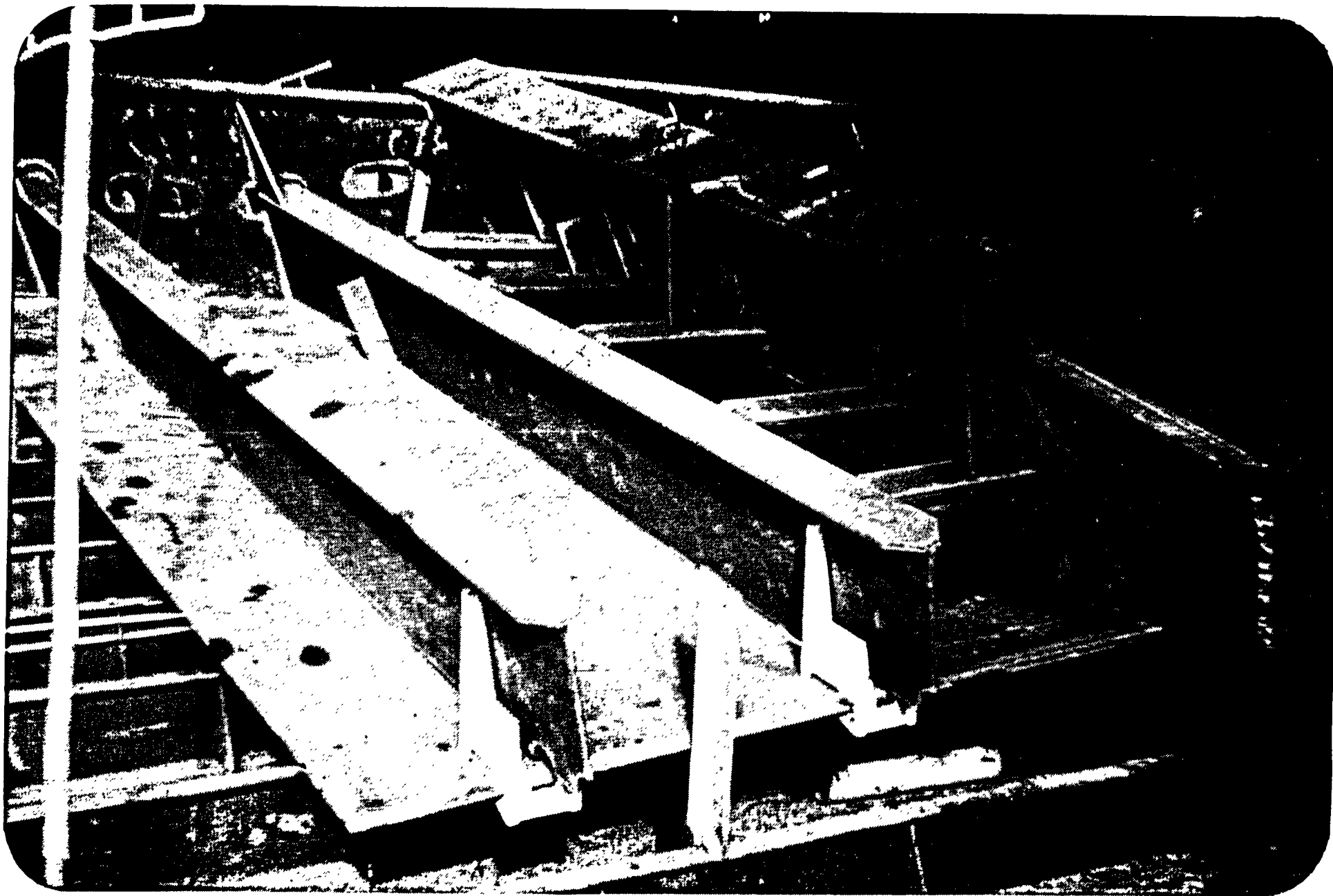


Flexible couplings temporarily fixed on-unit. IHI, Kure.

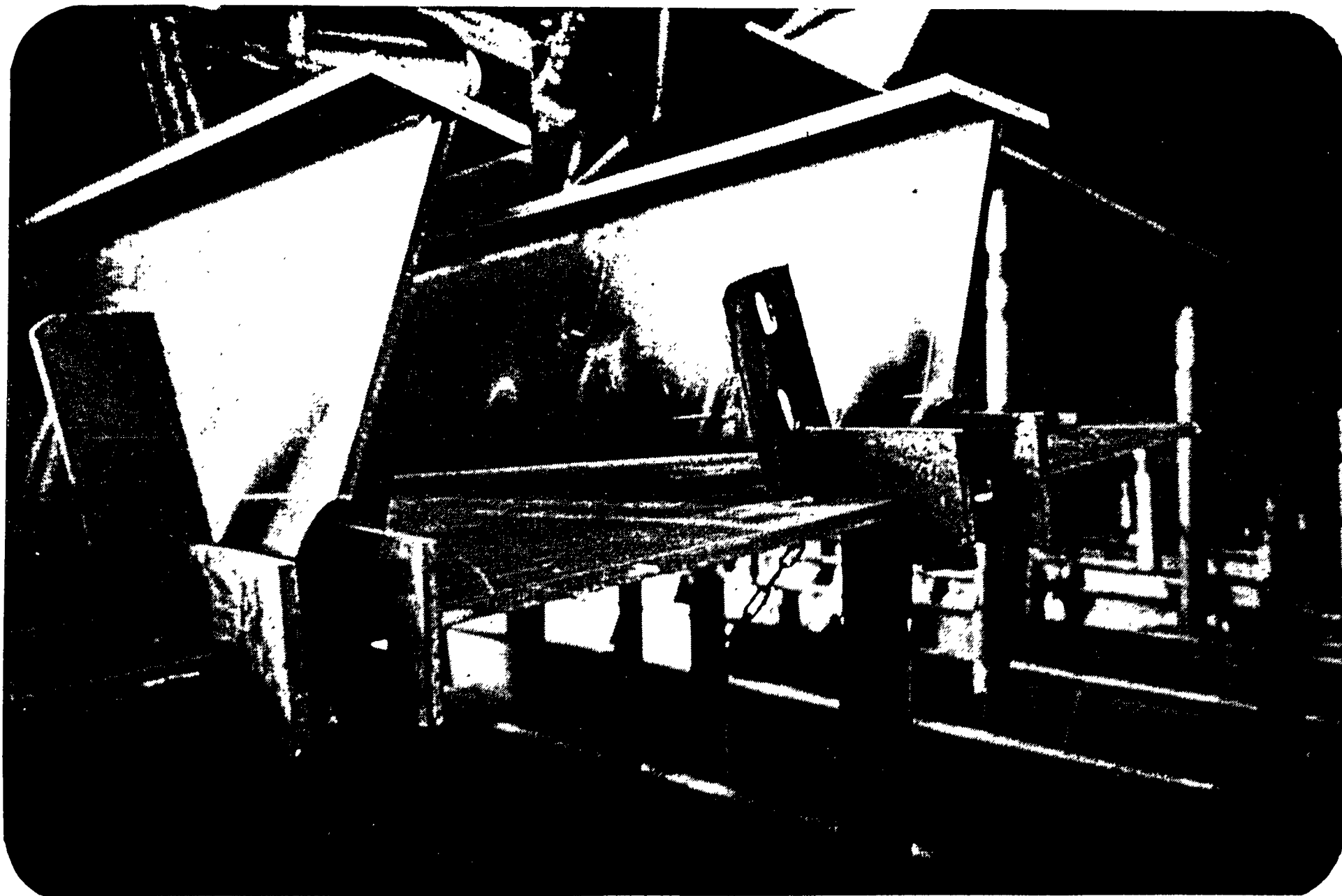




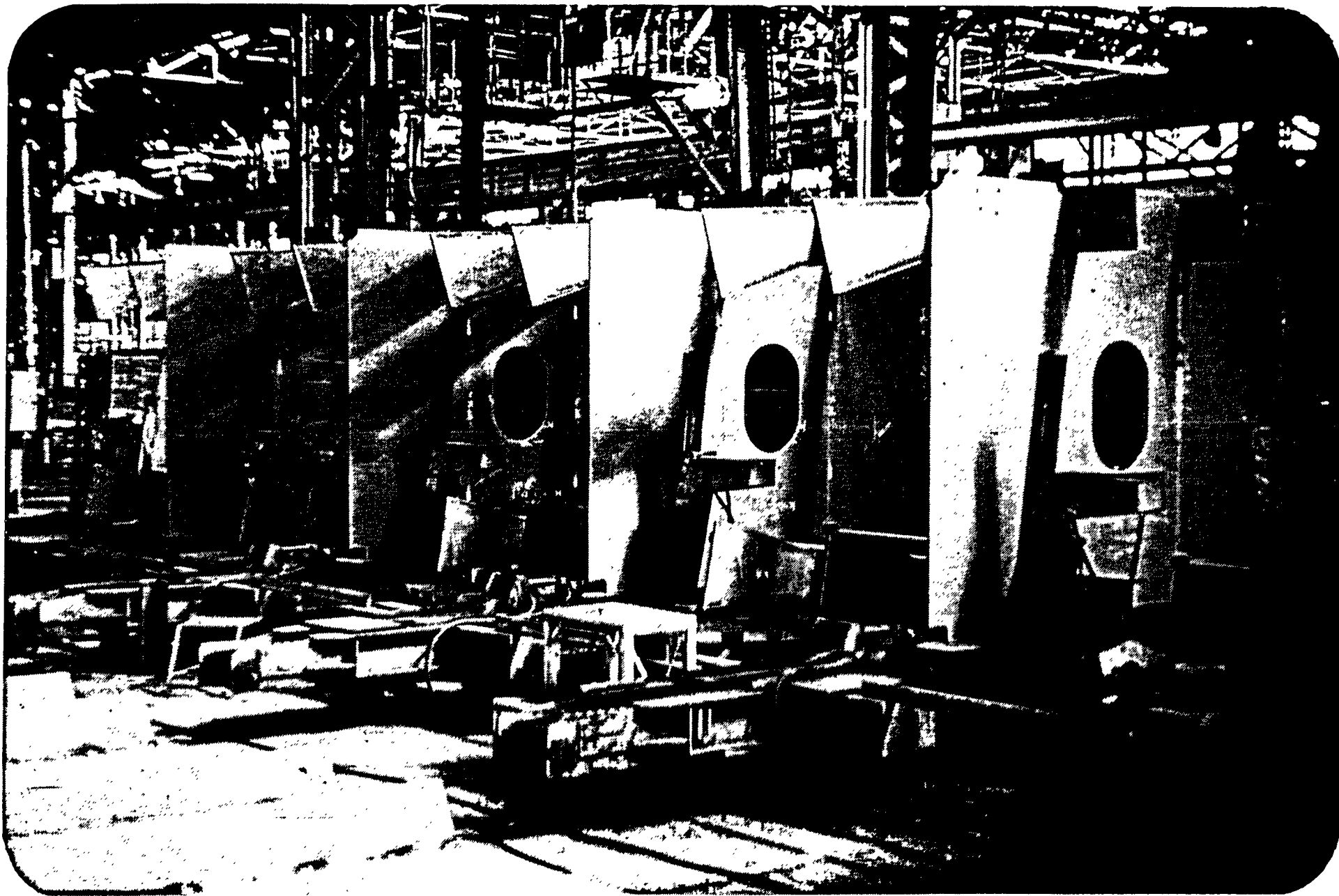
Connection of units with flexible couplings. NKK, .Shimizu.



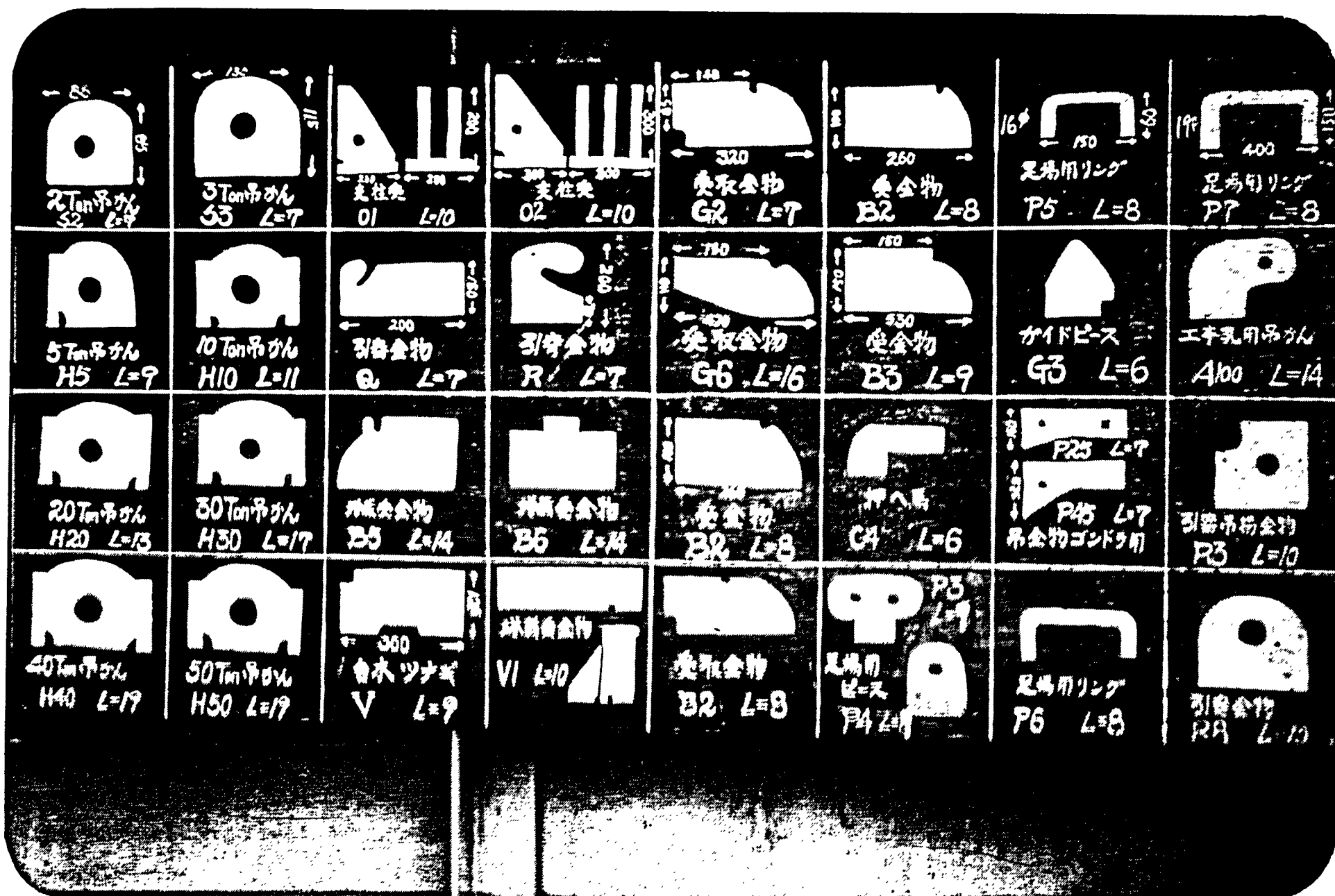
Jigs used for curved-panel structural assembly, IHI, Aioi.



Jigs used for curved panel structural assembly. IHI, Aioi.



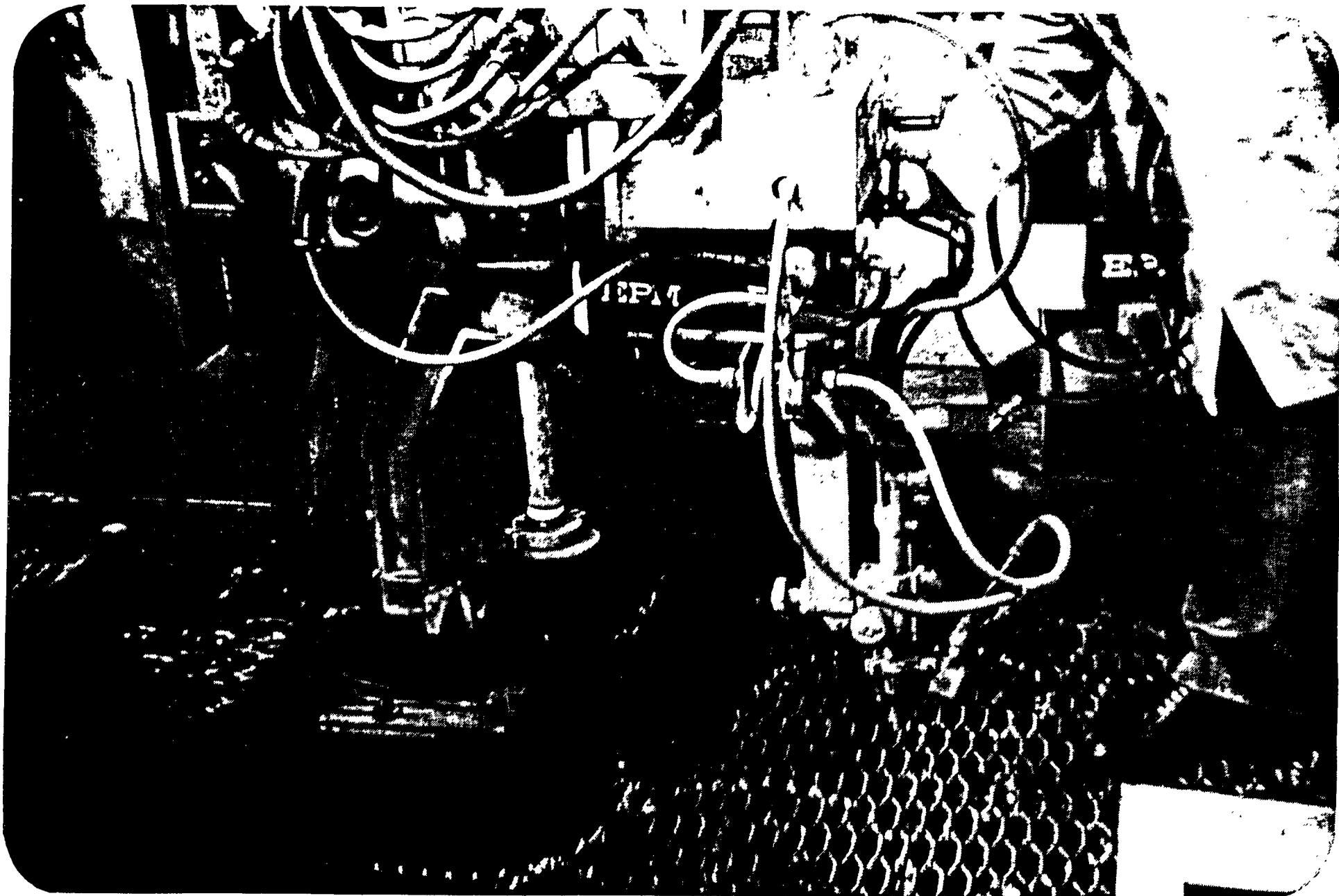
Egg crate steel assembly mechanized jig. NKK, Shimizu.



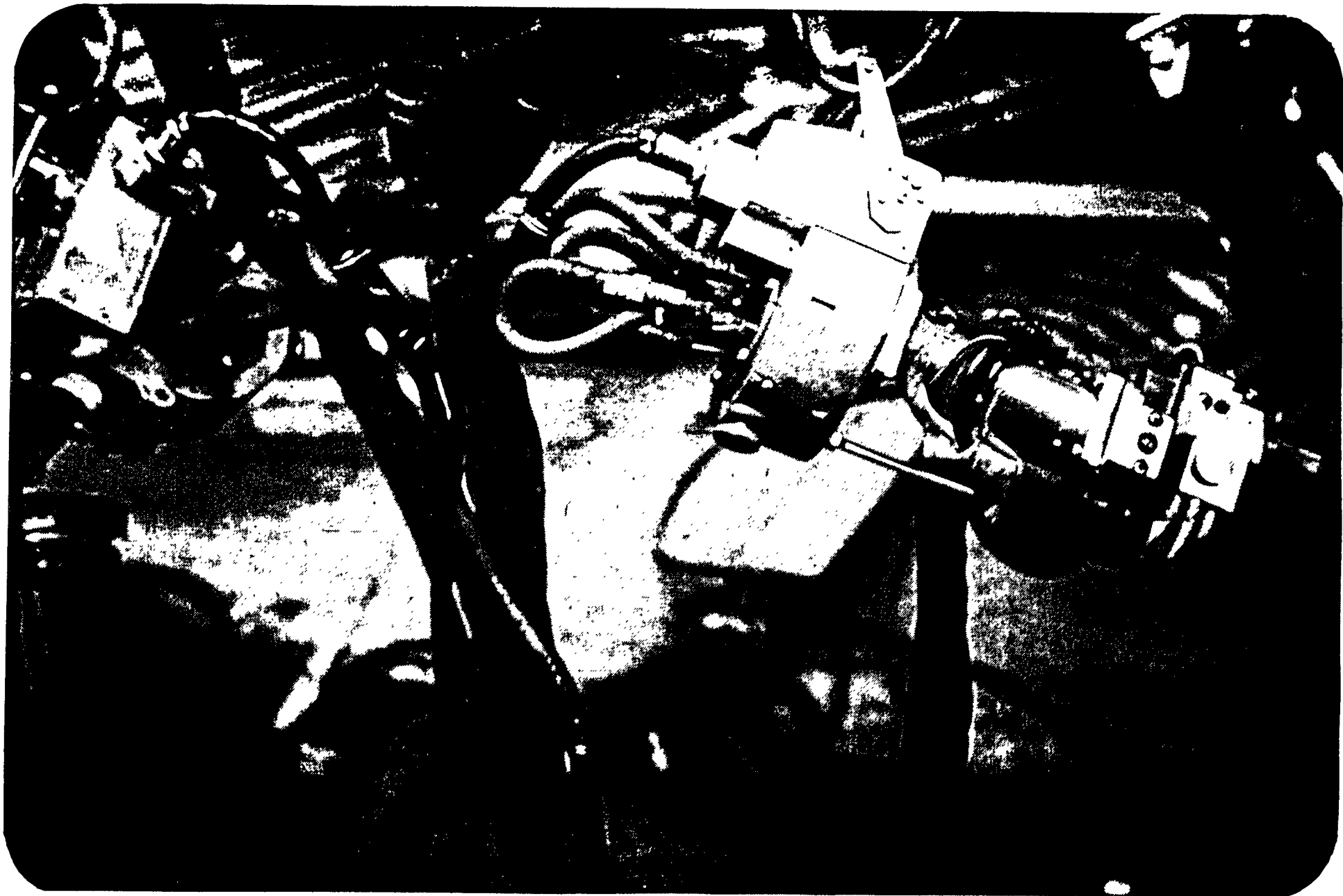
Scheme for lifting pads located near pad storage area. IHI, Kure.



Heat line fairing, to correct for welding distortion. IHI, Kure.



Koike (Japanese manufacturer) plasma N/C cutting machine with vented table. It produces significantly less noise than conventional plasma and no water table is needed. NKK, Shimizu.



Portable tube welder for boiler fabrication. IHI, Aioi.



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## APPENDIX A

The following nine critical elements were extracted from reference 1.

	Level of Difference Foreign Higher Than U.S.
C1. <u>MODULE BUILDING</u>	1.1
<u>Description:</u> This refers : to assemblies of auxiliary equipment, pipe and valves in self-supporting modules ready to be placed aboard ship. This could include pipe assemblies such as reducing stations, heat exchangers and pumps, etc.	
<u>Points Evaluted:</u> Extent of Module <b>Building</b> , When Module Installed, <b>Testing</b> .	
C2 . <u>OUTFIT PARTS MARSHALLING</u>	.6
<u>Description:</u> The collection into one kit or area all the material, technical information and tools needed to construct a module or discrete piece of work.	
<u>Points Evaluated:</u> When Marshalling Takes Place, Scope of Marshalling.	
C3 . <u>PRE-ERECTION OUTFITTING</u>	.5
<u>Description:</u> This is concerned with the degree of outfitting done on steel work prior to erection on the ways or building dock.	
<u>Points Evaluated:</u> Percent of Pre-erection Outfitting of Total Outfit, Scope of Pre-Erection Outfitting in % (approx.).	

	Level of Difference Foreign Higher Than U.S.
D2 . <u>ERECTION AND FAIRING</u>	.8
<u>Description:</u> This pertains to erection and fairing on ways or in building tools.	
<u>Points Evaluated:</u> Unit Size, Hanging Time. Dimensional Control, Alignment Methods, Fairing.	
D4 . <u>ON BOARD SERVICES</u>	.6
<u>Description:</u> This Dertains to services such as electricity; water, compressed air, other gases--on board ship on ways, in building dock and outfitting pier.	
<u>Points Evaluated:</u> Extent of Services, Services Configuration, Housekeeping.	
D8 . <u>HULL ENGINEERING (INSTALLATION)</u>	.6
<u>Description:</u> Installation of deck machinery (e.g. , steering gear, winches, windlasses) in units, blocks, or the ship after erection.	
<u>Points Evaluated:</u> Timing and place of installation, Trades.	
G1 . <u>SHIP DESIGN</u>	.7
<u>Description:</u> Ship Design to support contract actions and to provide a basis for production drawings. Typically includes: general arrangement, lines, shell plates, midship section, system drawings, and specifications.	
<u>Points Evaluated:</u> Shipyard role, Methods, Data, Research.	
G6 . <u>PRODUCTION ENGINEERING</u>	.7
<u>Description:</u> Production Engineering includes plant layout, equipment design, methods, standard practices and design for production. Deals with how the ship is to be built.	
<u>Points Evaluated:</u> Organization, Scope, Products.	

Level of Difference  
Foreign Higher Than  
U.S.

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H1. ORGANIZATION OF WORK

1.0

Description: The amount of flexibility allowed management in the assignment of work to the separate trades.

Points Evaluated: Trade restraints, area supervision work station organization.

## APPENDIX B

The following are brief biographies of the U.S. Team.

### CHIRILLO, LOUIS D.

Mr. Chirillo has a B.S. degree from the U.S. Maritime Academy and a Naval Engineering degree from Massachusetts Institute of Technology. His experience of more than 30 years embraces all phases of shipbuilding. His articles have appeared in the Naval Institute Proceedings, The Naval Engineer's Journal and SNAME publications. Currently he is the Research and Development Program Manager at Todd Pacific Shipyards. He has made several trips to Japanese shipyards and is very familiar with Japanese shipbuilding technology.

### JAQUITH, PETER E.

Mr. Jaquith is current Manager, Production Planning and Control at Bath Iron Works, In Bath, Maine. He is a graduate of Webb Institute of Naval Architecture and has had over 14 years experience in various aspects of planning and production at Bath Iron Works. His current responsibilities are for Planning, Scheduling and Labor Control for all new construction at Bath.

### JONSON. CHARLES S.

Mr. Jonson is a consulting engineer with Science Applications, Inc., La Jolla, California. He is a graduate of Whittier college and has over 12 years experience in shipbuilding with such companies as Todd Shipyards and National Steel and Shipbuilding in such areas as Engineering Design, Production Planning and Scheduling and Management Systems. A member of SNAME and APICS he is the author of technical articles and has made many presentations to technical groups.

### McQUAID, JOHN J.

Mr. McQuaid is the former Vice President of Yard Operations at National Steel and Shipbuilding Company in San Diego. He has over 40 years of experience in almost every facet of the shipbuilding business. Mr. McQuaid is a member of SNAME and has written articles and made presentations on Japanese shipbuilding.

PETERSON , ELLSWORTH L.

Mr. Peterson is the President of his own shipbuilding company, Peterson Builders, Inc. He is a graduate of the U.S. Maritime Academy, Kings Point, New York, and has spent over 30 years in the shipbuilding business. Currently he is the chairman. of SNAME Ship's Production Committee. Mr.. Peterson is a member of SNAME and has made numerous presentations at shipbuilding technical meetings.

VANDER SCHAAF, JAMES R

Mr. Vander Schaaf is currently Senior Naval Architect with the Shipbuilding Technology Group within IITRI. He has more than 9 years of practical experience in all phases . of software design, development and implementation for ship design and construction applications. He has a B.S. and M.S. degrees in Naval Architecture and Marine Engineering from the University of Michigan and an M.S. degree in Computer Sciences from John Hopkins University.